



# Light and LIGHTING

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This Golden Jubilee issue of *Light and Lighting* heralds a new epoch in the history of the only independent specialist lighting periodical in this country. What developments in the production and utilisation of light will occur as those of the yet unborn years of this epoch come and go will be described in our pages in due course. We do not now venture to predict them, for recent experience has shown that so swift—and startling—is the march of physical science that truth may well prove stranger than prediction even in matters of light and lighting. As for the 50 years surveyed by the articles featured in the present issue—unforgettable though they are for their world-shaking strife—they were eventful years for the science, the art and the practice of lighting, and in them was born the professional lighting engineer or designer. Now the question—and the challenge—is “where do we go from here?”

## Our Golden Jubilee

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# THE FIRST HALF CENTURY

## *Two Jubilee Messages*



**FROM THE RT. HON. VISCOUNT CHANDOS, D.S.O., M.C.**

Those responsible for the design of our houses and offices give much thought to the siting of the buildings and to the windows, because we all realise that good lighting affects our health, our work, our safety and our enjoyment. But when daylight fades into darkness we find that the same amount of care has not been spent upon the lighting inside the building. I commend this journal to you because one of its tasks during the last 50 years has been to work for the improvement of all forms of artificial lighting.

*Chandos*



**FROM JOHN W. T. WALSH, O.B.E., M.A., D.Sc.**

*President, International Commission on Illumination*

It has frequently been pointed out, sometimes reproachfully and always with regret, that there is no inconsiderable time lag between the completion of a piece of work by a scientist or technologist and its application in the daily life of the "man in the street." There are, no doubt, many good reasons why some delay is inevitable but anything that can be done to shorten it is supremely well worth doing, and it is here that the technical journal plays such an important part. Passing from the general to the particular, it is difficult to over-estimate the value of the work done during half a century by *Light and Lighting* which, in this country, bridges the gap between the lighting technologist and the user of light, i.e., the man or woman in the home, factory, office, school or where you will.

Lighting technologists in Great Britain confer frequently under the auspices of the Illuminating Engineering Society and a number of specialists from countries all over the world meet in conference every four years at sessions of the International Commission on Illumination, the CIE. Both these bodies publish the results of their deliberations periodically, but not even the most optimistic lighting engineer would imagine that these publications by themselves form a sufficient link between him and the general public. He looks to *Light and Lighting* to act as his interpreter and he does not look in vain. Here he has a journal which, by its method of presentation, makes the latest news of his activities interesting to a wide circle of readers in many walks of life. As the subject develops more and more specialisation becomes inevitable, the need for such a journal becomes continually greater. It follows, therefore, that everyone interested in the improvement of lighting standards generally must hope that *Light and Lighting* will continue to flourish and carry on in the future the work it has performed with such conspicuous success for the last 50 years.

*John W. T. Walsh*

*The special cover for this Golden Jubilee issue was designed by John and Sylvia Reid.*



## Once a month for fifty years



**Leon Gaster—  
the first Editor, from 1908  
to 1928**

A LITTLE more than 50 years ago—to be precise, on August 30, 1907—a company was incorporated “to establish, print and publish a magazine, newspaper or newspapers in London or elsewhere, in particular for the purpose of furthering the interests of illuminating engineering.” That company was, and is, the Illuminating Engineering Publishing Co. Ltd. Four months after its incorporation it published, in January, 1908, the first number of the new magazine under the title *The Illuminating Engineer*.

Although this title was retained for 28 years, it gradually became apparent that it was inadequate to indicate the nature and scope of the journal and that it tended to “warn-off” certain non-engineering classes of reader to whom the journal was, in fact, of interest and whom it was most desirable should be reached. Among these classes, some that come to mind immediately are architects, interior decorators and industrialists. Obviously there are many others. Indeed, all who have eyes to see have also a direct interest in lighting, but it was never thought that the magazine could be a “popular” one circulating widely among the general public. That would be very improbable because, although the demand for lighting is universal and almost incessant, interest in its techniques is not and is never likely to be. However, it was clearly desirable to describe the journal more faithfully and so, eventually, it was sub-titled “The Journal of Good Lighting.” Later still its original title was discarded altogether in favour of the present one, *Light and Lighting*.

When the magazine made its debut there was no Illuminating Engineering Society in this country. That body was inaugurated 18 months after the foundation of the publishing company and it found at its birth an established lighting journal. Had it been otherwise—had the journal died in infancy—there may well have been no Society. As it was, the journal was available to help the new Society, which was able to use it immediately for the information of its members and the recording of its proceedings. The close association between the Society and the journal has thus been almost lifelong, but the mutual independence of the publishing company and the Society has always been maintained. The journal is sent to every member of the Society, but it also has an extensive external circulation and its own policies and management.

The institution of the new journal was due to the efforts of Leon Gaster, who became its first Editor. Gaster was himself a practising lighting engineer and also a technical journalist with international connections. He knew that the state of the lighting art left much to be desired and he

1908.

*The ILLUMINATING ENGINEER*

THE JOURNAL OF SCIENTIFIC ILLUMINATION

EDITED BY LEON GASTER.

VOL. I.

JAN. 1908 TO DEC. 1908.

10/- YEARLY

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The cover of the first volume

believed there was room for a special journal that, without bias towards any of the illuminants then in common use, would publish articles on all aspects of lighting, including developments of light sources and lighting equipment, photometry, methods of lighting design, the physiological considerations necessary in planning good lighting, descriptions of new and interesting installations, and so on. The journal was, in fact, to gather from all available sources at home and abroad useful information concerning the developing science and art of lighting and to be a channel for the communication of ideas and knowledge that would lead to the advancement of lighting practice.

The journal began its career with a page  $9\frac{1}{2} \times 6\frac{1}{2}$  in. in size—similar to that of many of its contemporaries. It was well printed on good paper with plenty of illustrations by line and half-tone blocks. It was published monthly—as it still is. It contained plenty of “meat,” including articles by the most able and authoritative writers, and it was good value at one shilling a copy.

Gaster's able assistant from the outset was John Stewart Dow, who did most of the work involved in preparing the journal for the Press and made numerous contributions as a staff writer. He was Gaster's complement—the academic half of the partnership, for that, in effect, was what it was. Dow had taken his degree at Imperial College and had already designed one of the portable illumination photometers then in use when he joined forces with Gaster.

The progress of the journal for a number of years was uneventful. It gained ground, but it did so very slowly.

Although everyone needed lighting (and artificial lighting as widely used at that time was still far from perfect) not nearly enough people showed a lively interest in the advancement of lighting techniques and lighting practice. By the mid-twenties, however, when the journal was well on in its “teens,” a quickening and spreading of interest in lighting was apparent. There had been considerable Government interest in the matter of factory lighting, and the lighting of schools, public buildings and streets was much under discussion. A new body had been formed—the Association of Public Lighting Engineers—which until such time as it was able to publish its own journal, found in the *Illuminating Engineer* a convenient and suitable medium for communicating with its members.

#### For a Wider Public

So, in 1925, the journal set out to adapt itself to the needs of a wider public. With the first number of its eighteenth volume it assumed a new guise. The page size was increased to 13 by 9 in., so that in this respect it joined that class of magazines exemplified by “*The Tatler*.” The increased page size enabled the Editor to use better illustrations and enabled advertisers to display their announcements more effectively. The needs of advertisers must be carefully regarded for, not only must all journals rely heavily upon revenue from advertisements if they are to be sold at a price that will attract subscribers, but advertisers announcements are part of the service a technical journal renders to its readers, who naturally want to know what is available and from whom. The original name of the journal was retained but it was at this time that the second title was added “*The Journal of Good Lighting*,” and the price was reduced to 9d.

In 1928 Leon Gaster died and J. S. Dow became Editor of the journal—20 years after its foundation and after 20 years of service as its assistant editor. No one could have been more interested in the journal and have devoted more time to its production. He was unmarried, and the journal had become and continued to be his “child.” Like his predecessor, however, he also acted as Hon. Secretary to the IES, but this involved no division of his interests, though it divided his labours.

Under J. S. Dow, the journal continued to thrive and maintain a high standard as a technical periodical at a modest price. With the advent of the 1939-1945 war difficulties began, as they did for other publications. By the



The second  
Editor,  
J. S. Dow—41  
years with the  
journal



**G. F. Cole, the present Editor**

beginning of 1942 paper restrictions forced on the editor a serious cut in the amount of material which he could publish and a reduction in page size to 9 x 6 in. These restrictions were still in force in 1948, when the general post-war rise in costs made it impossible to avoid raising the price of the journal to what it had been 40 years' before—one shilling a copy.

In August of that same year J. S. Dow died. For nearly 41 years he had laboured unremittingly for the journal but he was not spared to see it emerge from the limitations forced on it by early post-war conditions. Fortunately, some time before, the growing burden of work and the awareness that the load must be shed ere long, led him to cast around for a likely successor, and in 1946 he had found someone who, to his perceptive mind, held great promise. This was G. F. Cole—just released from his duties with the armed forces and eager to take up an interesting civil career. So, with a technical knowledge of lighting gained during pre-war service in a branch of the lighting industry, Cole began to understudy Dow. It was not long before he was appointed Secretary to the IES, thus maintaining the bond between the Society and the journal.

#### No Crisis in the Office

Thus the death of J. S. Dow, unexpected as it was, involved no crisis in the editorial office. By now well versed in the production of the journal, G. F. Cole carried on and the remaining issues of the 1948 volume duly made their appearance without noticeable change. Meanwhile, the directors of the company formally appointed Mr. Cole to the editorial chair and he at once began to formulate plans for the improvement of the journal.

There were still formidable difficulties to contend with, including paper rationing and a succession of increases in production costs. Nevertheless, some improvements were effected though, by 1951, the price had to be increased to 1s. 6d. a copy. A drive for more subscribers and more advertisers was embarked on and the overseas circulation of the journal was increased. The appointment of Miss Joan Wood as Advertisement Manager brought an important part of the journal's business under the control of one who has continuously handled it with competence, enterprise and enthusiasm, tempered, let it be added, with feminine charm.

The small page size to which the war had reduced the journal set obvious limits to the improvements which could be introduced. The number of pages had gradually been increased, the quality of the paper improved and there was better presentation of the material published. But it was impossible to use illustrations of adequate size and to practise the niceties of modern display and lay-out. The title of the journal had been changed to *Light and Lighting* in 1936, but in 1954 the journal appeared in a new guise having a re-designed cover and a page size of 11 x 8 in. Unfortunately, further rises in production costs forced the price up to 2s. a copy but, on the other hand, the journal was so substantially improved as to win unqualified approval from readers and advertisers alike.

#### Gaining Prestige Abroad

So far so good, but neither G. F. Cole, the enthusiastic but never-complacent Editor, nor the directors of the company could rest content with what had yet been achieved. The circulation of the journal was expanding and it was gaining prestige at home and abroad. But it was not yet good enough—perhaps that is something it will never be in the eyes of its severest critics, its producers. So improvements continue to be made from time to time. To increase its appeal to architects, Maurice Jay was appointed as an editorial consultant to obtain and present material of particular interest to the designers of buildings and interiors, and in 1956 the cover was again re-designed, with its now-familiar bold colouring, and the practice of "bleeding" illustrations at the edges of the pages (to take the fullest advantage of the space available) was adopted.



**Miss Joan Wood,  
Advertisement  
Manager**

The paper used, the legibility of the type, the lavish use of illustrations, the style of lay-out and the interest and quality of the material published have put *Light and Lighting* in the forefront of lighting journals. It is, of course, the only independent journal devoted to the subject in Britain, but it has subscribers in no less than 57 other countries. Recent application of accredited techniques for "consumer research" have shown that each issue of *Light and Lighting* is seen by about 25,000 readers. Large as this number seems, it is the publishers' aim to increase it substantially and, as the journal starts its second half-century, they are confident of success.

H. C. WESTON.

# 1 Light Sources

By H. R. Ruff, B.Sc., M.I.E.E.\*

**I**N 1908 flame sources were well established, the incandescent mantle had made gas a major contender in the field of general lighting, the electric arc was well established for area lighting, and much of the pioneering development of incandescent lamps had been completed.

Articles in the first volume of *The Illuminating Engineer* clearly show the close connection between the development of light sources and the development of means for supplying power. While some 11 articles are concerned with gas lamps, 12 with arc lamps and 12 with incandescent filament lamps, there are 14 articles dealing with the use of acetylene and a hint of developments to come were given in two articles on electric discharges.

Much of the technical development was due to the replacement of arbitrary assessment by measurements which made it possible to determine just where energy was being used and where wasted, and how much of it was being converted

into useful light. In 1908 there was still no agreed "standard of light" and a proposal submitted to the International Electrotechnical Commission meeting that year in London for an "international candle" was deferred to allow the gas and electrical industries in the different countries more time to think about it. The eventual development of instruments that could measure light and allied radiation accurately enabled fundamental discoveries in chemistry and physics to be evaluated and applied.

The development of measurement techniques has been equally useful in examining unsupported theories of possible dangers arising from the introduction of new light sources. Even in 1908 danger from erythema as incandescent filaments were raised in temperature was being suggested—although a more serious problem was that of ventilation where sources burning oxygen were used.

#### Sources Using Combustion

While sources relying on combustion have gradually been replaced for general lighting owing to their relatively low efficiency and inconvenience, some have continued to fulfil a useful function as portable light sources since the amount of energy that can be stored chemically in a given weight and volume for combustion still greatly exceeds that which can be stored electrically which in many cases more than compensates for the lower efficiency of the light source.

In many parts of the country such sources continue to fulfil a very useful function in providing lighting where other means are not available. The paraffin oil lamp has been greatly improved by flame studies resulting in non-luminous combustion and the use of mantles, and the adoption by the gas industry of containers of gas of the butane/methane types has provided some competition.

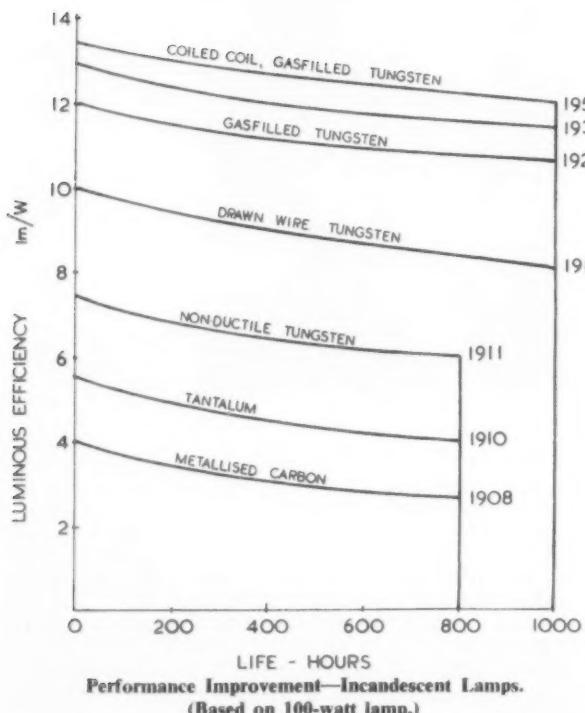
In the period up to the late 1930s the gas industry played a leading part in lighting and improvements in burner and mantle design enabled it to hold its position, particularly in street lighting, in spite of keen competition from electric sources.

For many years wick oil lamps were the mainstay of all portable lamps for transport. Acetylene units made serious inroads on this market by providing very much brighter compact lamps but when the servicing of these proved somewhat laborious it was to the rapidly developing electric lamp that the users turned.

#### Incandescent Electric Lamps

The major development in lighting sources during the past 50 years has probably been the wide adoption of the tungsten filament lamp. This has been largely due to the improvement in efficiency and reliability achieved through scientific research,

\*Research Laboratories, B.T.H. Co. Ltd., Rugby.



allied to ingenious invention of detailed modifications enabling lamps to be made in vast quantities by automatic machinery.

By 1908 the carbon filament lamp was in quantity production and drawn wire metal filaments had been introduced showing the possibilities of higher efficiencies and brightnesses though the metal filaments were weak compared with the carbon ones. For this reason, in the early part of the period variations of carbon lamps (e.g., the Gem lamp), in the processing of which a hard tough shell of graphite was formed around the main filament, had some popularity owing to their suitability for manufacture by the carbon filament techniques and their slightly higher efficiency. The Siemens and Halske tantalum lamp represented a compromise between strength and efficiency which attracted considerable use in the early years.

The major contribution in the search for the most suitable filament material was made by Coolidge, who discovered that, while most materials can be worked best when heated above their annealing points, the metals tungsten and molybdenum become more ductile when worked below their annealing temperatures. By working these at the temperature just below the annealing temperature, ductile tungsten is produced which is fibrous in form but when heated above its annealing point re-crystallises and becomes more brittle. Many detailed improvements have since been made by the addition of materials to increase the strength of the crystalline form, particularly with the view to eliminating slip between crystal surfaces which gave sagging filaments, a common trouble in the early days of the lamp. This work was largely completed around 1918 and established the supremacy of tungsten for filament lamps. The reliability of these filaments enabled the efficiency to be raised to around 10 lm/W with a 1,000-hour-life lamp.

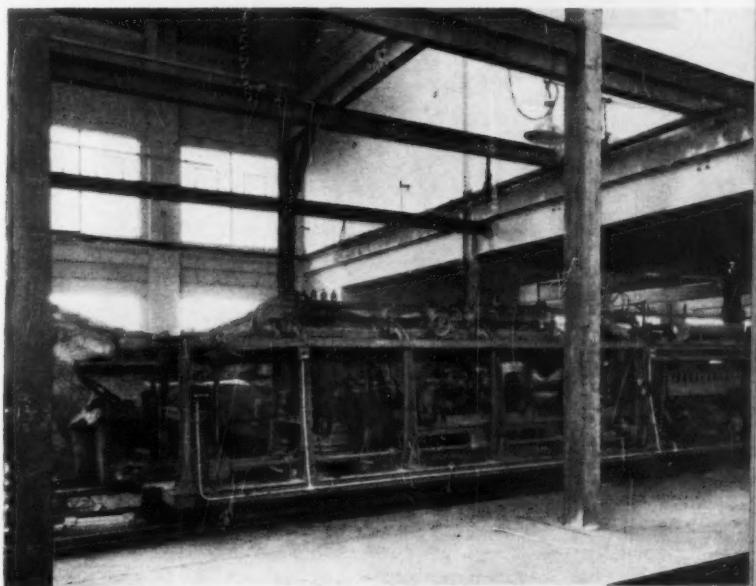
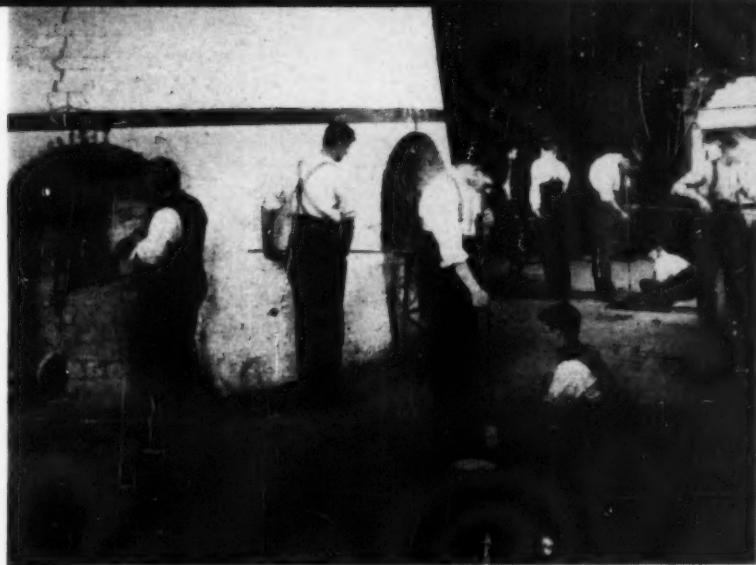
### The Gas-filled Lamp

The next major gain in efficiency and brightness of the filament source came with the introduction of inert gases into the bulb. After two years of research, Langmuir proved that the major factor in the blackening of well-made tungsten lamps was the evaporation of the filament. This blackening could be reduced by the presence of an inert gas, the molecules of nitrogen or other gas tending to deflect the evaporating tungsten atoms back on to the filament. The introduction of the gas filling, however, meant that the filament had to be redesigned; in coil form the evaporation rate could be cut down without that loss of energy through convection which had previously offset the gain in intrinsic efficiency from the filament through the attainment of higher temperatures in the gas.

The adding of gas filling to the ductile tungsten lamp in 1920 greatly accelerated the predominance of the electric lamp for general purpose lighting. A further improvement was made with the introduction of double coiling, which also proved helpful in extending the use of these lamps for projection purposes where the maximum amount of filament has to be put into the minimum space in a form suitable for the optical system.

Alongside this scientific research work on the source there was probably even greater effort being put into attempts to cheapen and simplify construction. Even in 1910 a small portion of platinum was frequently used to form a reliable seal to the lead-in wires. In 1913 nickel iron sheathed with copper was introduced and has been the major sealing material ever since.

Elimination of the external exhaust tip by forming the exhaust tube into the pinch and stem



simplified manufacture and improved reliability. Methods of manufacture of all the component parts have progressed until in place of the hand blower we now have the giant ribbon machines producing bulbs at rates of some million per day, automatic coiling machines producing filaments from diamond drawn tungsten wires, and lamp making units by which the components are almost automatically assembled into complete incandescent lamps.

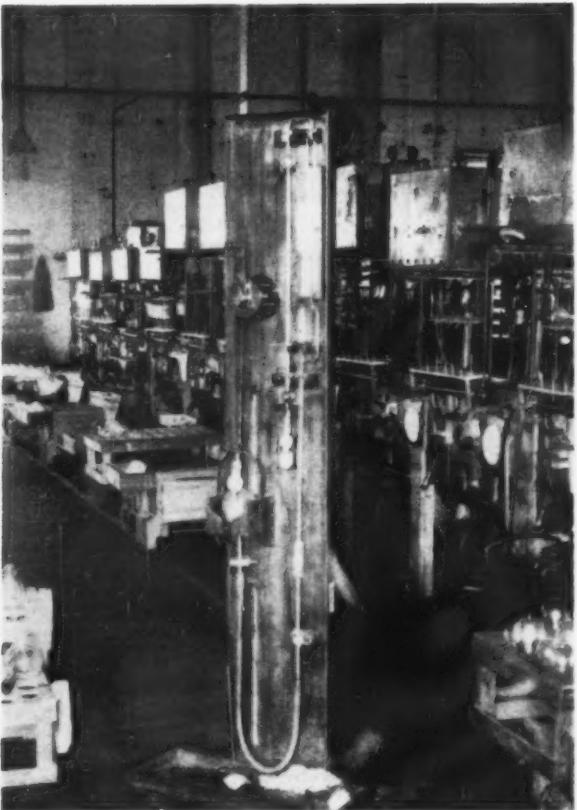
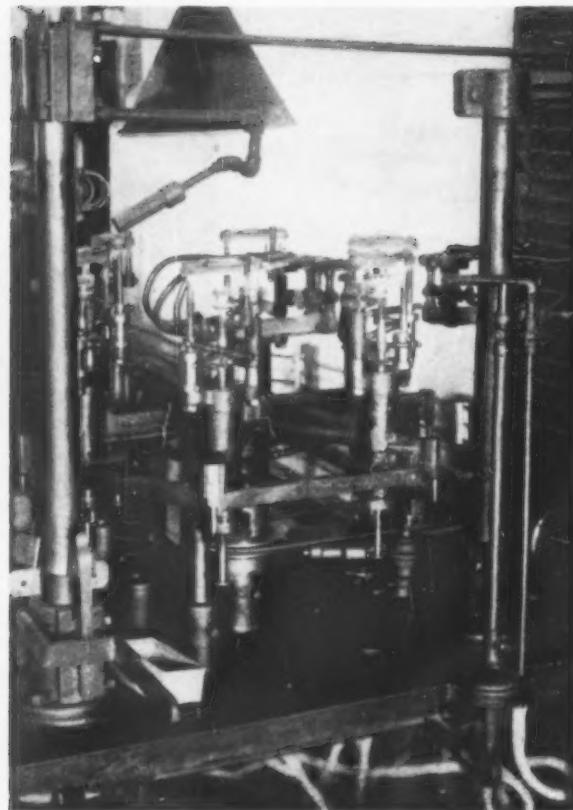
Lamps now range in size from fractions of a watt to many kilowatts. General purpose lamps have been improved by obscuring the filament brightness with double internal frosting or pearling and more recently by coating the inside of the bulb with silica particles. Colours have been introduced to extend the field to that of decoration and carnival. Integral reflectors now permit more compact flood and spot lamps and give improved optical performance.

### Electric Arcs and Discharges

The electric arc lamp, discovered by Davy in 1802, had entered the main lighting field in 1880,

### 1910-1950

**Top, hand blowing lamp bulbs, compared with (above) automatic blowing by a "giant" ribbon machine.**



1 | 2  
3 | 4

Four stages in the manufacture of filament lamps during the early part of the century : (1) flare making ; (2) filament mounting and flashing ; (3) sealing-in ; (4) exhausting.

and by 1908 was in an advanced state of development. The arc was essentially a high power light source and was introduced for outdoor lighting and large buildings. Many attempts had been made to produce efficient small low power arcs, but these largely ceased with the development of incandescent lamps. The necessary design for reliable feeding of the consumable carbons made these quite complicated and left scope for considerable ingenuity.

The arcs have retained their supremacy as high power sources for searchlights and cinema projectors and until recently were predominant for film studio lighting, but from time to time they have been challenged by the electric discharge lamps which came into prominence in the early 1930s.

In the late 1920s, frustrated by attempts to increase the efficiency of incandescent filaments, further attention was given to electric discharges in gases. Improvements in glasses had made it practicable to operate much higher temperature discharges in glass envelopes. The development of radiation-measuring equipment made it possible to examine just where the energy input to the discharge was being radiated for different conditions of vapour pressure. Measurements were made on electric discharges through many gases and vapours of which the two most important proved to be sodium vapour and mercury vapour.

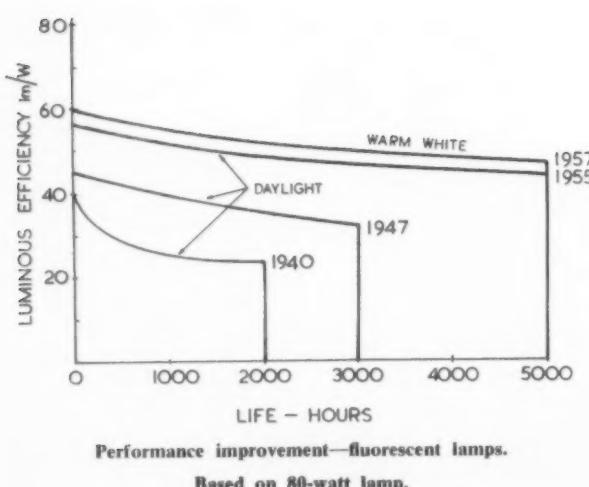
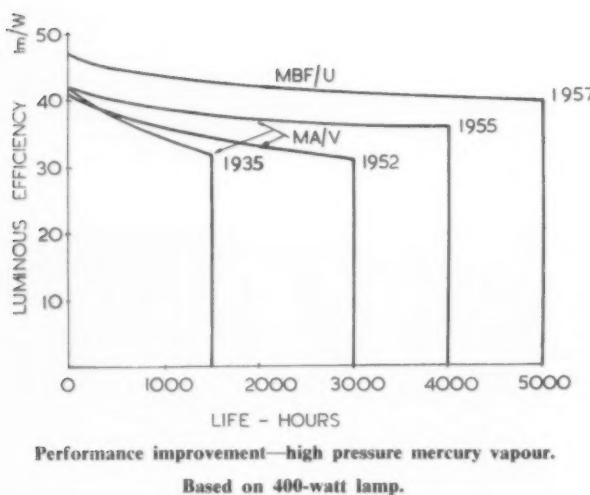
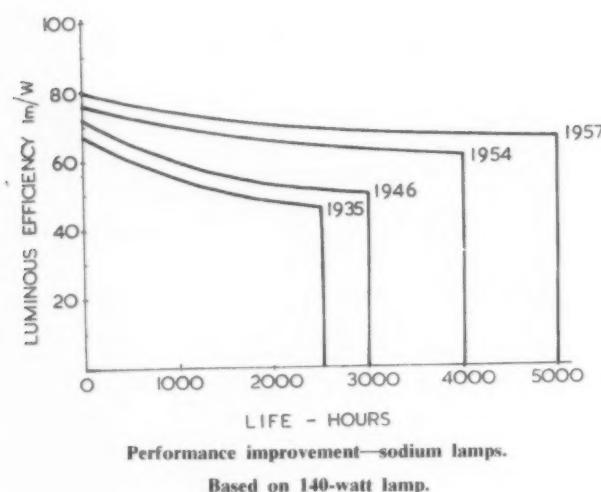
With sodium lamps a vapour pressure of a few microns gave optimum efficiency; this meant maintaining sodium reservoirs at a temperature of just under 300 deg. C. Practicable lamps were made possible by the development of glasses to

withstand the chemical attack of ionised sodium vapour. The sodium-borate or phosphate-type glasses which were developed to do this had unstable physical qualities. Many who worked in the early development of experimental lamps will have memories of the rather rapid liquefying of the glass which made it just possible—but only just—to make a seal before the tube became one big "drip." However, techniques were developed so that this glass could be put on in the form of a glaze, or as the inner skin of a two-ply glass. To obtain the temperature efficiently a form of vacuum flask was necessary and produced in either some integral or detachable form.

Experiments on mercury discharges had shown that whilst there was an optimum efficiency at relatively low vapour pressures (e.g., used for Cooper-Hewitt lamps) as these were increased still further a second and much higher peak was attainable. Pressures of the order of an atmosphere were necessary for this with temperatures of about 500 deg. C. for the mercury reservoir. Alumino-silicate glasses which would seal to tungsten or molybdenum were developed which would operate when red-hot. A single tubular glass jacket was sufficient to prevent air-currents cooling the arc tubes so that the power input was able to raise the temperature to give the required pressure. It was soon found that lantern enclosures could modify this, giving increased temperatures and pressures resulting in increased arc voltages and instability; this caused the lamp to go out. This extinction was all the more irritating as the lamp had to cool for some five minutes to reduce the pressure for re-striking but it was overcome before

**A modern group unit for the manufacture of tungsten filament lamps.**





the introduction of practical lamps by superheating the mercury vapour, achieved by inserting a definite weighed quantity for each size of arc tube.

Once again the initial introduction has been followed by considerable detailed improvements. The life of the electrodes has been increased by studies of the anodic and cathodic functions. Quartz was available as an arc tube material before the special hard glasses, but the difficulty of mass producing simple seals limited its use until the molybdenum foil seal was introduced. Improvements in efficiency arose from the use of still higher pressures necessitating higher temperatures and, by using small seals and small quartz tubes, lower wattage mercury vapour lamps became available.

### The Mercury Arc

Studies of the behaviour of the mercury discharge over wide ranges of conditions resulted in a better understanding of the physical principles involved and led to the practical achievement of sources giving light at specific wavelengths. The concentrated sources made radiation measurements through monochromators relatively straightforward, and these showed that considerable ultraviolet radiation was present in the discharge. By using Wood's glass for the jacket bulb it was possible to produce very convenient sources of long U.V. ( $3,650\text{\AA}$ ) and hence produce lamps for scientific studies of fluorescence.

While the theory of high pressure discharges was too complex for calculation, empirical measurements proved that for a given arc voltage the arc gap could be shortened as the vapour pressure was increased and the efficiency maintained. Thus from the lower brightness electric discharge was produced the super-high pressure mercury arc. Experimentally made in sizes up to 20 kW the lamp has established itself mainly as a 250-watt lamp which has successfully competed with the small carbon arc. At these higher pressures the introduction of cadmium and zinc to high-power lamps gave greatly improved colour, adding 10 per cent. red light with only 5 per cent. loss in efficiency. This enabled  $2\frac{1}{2}$  kW lamps and 5 kW lamps to be used in film studios for colour films. The run-up time restricted the use of these lamps for film projection although the 250-watt size proved useful in 16 mm. projectors.

For this reason attention was focused on rare gas arcs and in spite of reduced efficiency and brightness these may soon be competing with the carbon arc for film projection. Introduced in 1947 in a water-cooled form, the most successful of these is a 2 kW Xenon lamp which will operate from 30 volts D.C.—now conveniently obtainable using germanium rectifiers.

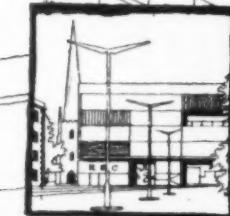
For general-lighting mercury lamps, improved colour rendering could be most efficiently obtained by converting unwanted ultra-violet radiation into red light. Introduced in 1937 using zinc and cadmium sulphide phosphors, these have been greatly improved and reduced in size by the introduction of phosphors of the magnesium germanate or arsenate types. Maximum efficiency is obtained by using quartz arc tubes passing the shorter U.V. which these can convert. The good colour rendering has enabled these more expensive arc tubes to be introduced and has paved the way for quantity production methods of pinch sealing which should help to reduce their cost.

### Fluorescent Lamps

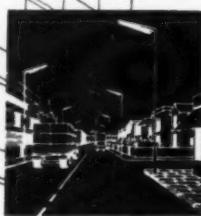
It is perhaps surprising that the work on mercury vapour discharges, stimulated by the attractive high luminous efficiency produced by working at high pressures, should produce as its most im-



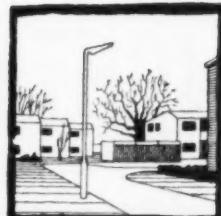
**one superb  
design**



FOR CIVIC CENTRES



FOR MAIN ROADS



FOR URBAN ESTATES



FOR TREE-LINED ROADS

Here at last is an all-purpose design for outdoor lighting that is both practical and elegant. The original lantern was chosen for lighting the new oil town of Kuwait in competition with British and foreign manufacturers. This successful design forms the basis of the Kuwait Unitary System which provides for every category of lighting from civic centres and main roads down to secondary roads and housing estates. The system is completely flexible and employs a high proportion of standardised and interchangeable parts and fittings. It makes possible completely harmonised lighting schemes on any scale; it covers every size and arrangement of outdoor lighting, and it allows for modification to suit changing conditions.

Maintenance is simple and there is no need to carry a wide variety of spares and replacements. The Kuwait Range has been approved by the Council of Industrial Design for inclusion in Design Review and is already widely used in the United Kingdom and overseas. If you would like complete information about the Kuwait Unitary System, write for leaflet F.27 or get in touch with your local Siemens Ediswan lighting engineer for advice—no obligation.

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portant result a low brightness very good colour lamp using mercury vapour at very low pressures. Radiation measurements showing that approximately 50 per cent of the input power could be radiated from the low pressure mercury discharge as short wavelength U.V. (2537A), allied to research into phosphors which showed that certain groups, such as silicates, tungstates, borates and phosphates could convert this radiation with almost quantum efficiency into visible light, led to the introduction at the end of 1938 of the tubular fluorescent lamp. With the mercury discharge giving less than 10 per cent of the light, and the radiation from the phosphors covering wide wavebands, the fluorescent lamp could be made to give normal acceptable rendering of colours. Instead of the physical determination of colour by the temperature of the source as in incandescent lamps there was for the first time a tremendous degree of freedom in choice of colour. As soon as such lamps became practicable efforts were made to standardise methods of measurement and to determine whether many colours would be necessary to make full use of these lamps. Some 5,000 colours distinguishably different could be made and by using different phosphors each of these could be made to render colour in a number of different ways.

The studies indicated that for general lighting conditions colour points approximating to daylight, sunlight, and the highest temperature obtainable with incandescent lamps would serve most purposes. Early American lamps operated at loadings that gave maximum efficiency, but views were expressed that the lamps should be constructed with a limited maximum brightness. Faced with the problem of using these lamps for wartime factories, we in this country established a higher loading design which has proved here to be a more economic compromise between efficiency and cost of lamp. It is now generally accepted that lower brightness and diffusion are best obtained by the luminaire, whether separate from or integral with the building design. Much thought is still being given to the question of higher loading which could further extend the use of these lamps.

#### Lamps for Special Uses

Often it is the special problem that enables a new light source to be developed; in turn, light sources have often helped solve allied problems and aided fundamental research.

The waste infra-red radiation from incandescent lamps has been put to good use for infra-red heating. Internal reflector mirrors have proved particularly effective as they are unaffected by atmospheric conditions. The latest tubular quartz heat lamp has enabled intensities as high as 50 kW./sq. ft. to be controlled to aid research into high-speed flight problems.

Near ultra-violet, both from high-pressure mercury lamps and from special fluorescent lamps, has made the examination of fluorescence convenient, and even the short ultra-violet in the fluorescent lamp discharge has been radiated through special glasses to kill airborne bacteria.

While the direct excitation of light from phosphors (electro-luminescence) is too inefficient for lamps, luminous panels provide attractive indicator units.

Modern light sources have greatly extended researches into the effect of light on plant growth and are also used for many photo-chemical processes.

Many special lamps have been developed for photography. In addition to high-temperature incandescent photo-floods there is the electrically fired photo flashlamp which has been concentrated in size and mass produced so that it is in many cases used even in daylight to enhance high-

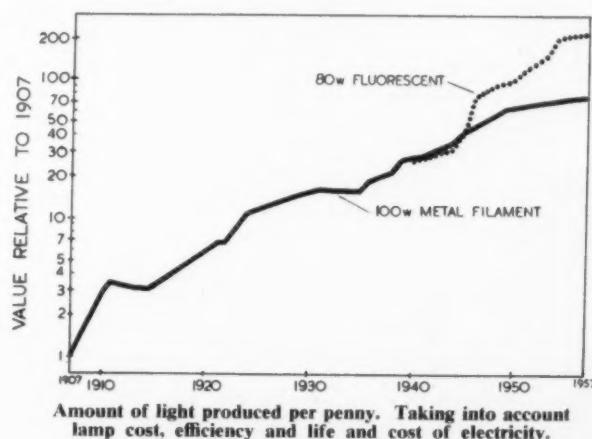
light effects. Speed of motion has been arrested still further by the flash tubes. These have been developed to operate from simple batteries for normal photography and have been developed in many shapes and sizes to give synchronised flashes for the stroboscopic viewing of mechanisms and for varied research purposes.

#### Conclusion

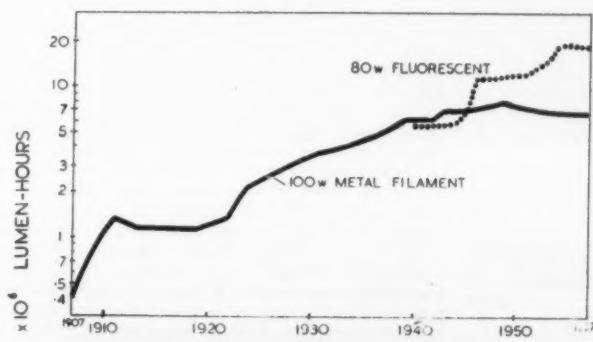
The development of electric lamps during the past 50 years owes much, particularly in the earlier years, to competition from other light sources. In turn, the continuous progress made by the lamp engineers and physicists has challenged and stimulated the lighting engineer who welcomes the new tools with which he is provided though still finding new ways of using the old ones.

Perhaps the most important point about the light sources which have been introduced is that with each new development the cost of light has steadily decreased—and this during a period when the cost of almost every other service and commodity has increased. From progress during these 50 years, 50 times more light is now obtainable for each penny spent. Taking into account the changes in the value of money, this means that the economy of producing light has been improved more than two-hundredfold. The industry, through research, invention and mechanisation, has undoubtedly had a major effect on the way of life and standard of living of the whole community.

The author wishes to thank colleagues in the B.T.H. Research Laboratories and in the Engineering Department of the A.E.I. Lamp & Lighting Co. Ltd. for their help in preparing this article.



Amount of light produced per penny. Taking into account lamp cost, efficiency and cost of electricity.



Relative value of light produced. Also taking into account change in internal purchasing power of sterling.

## 2

# Lighting in the Home

By D. W. Durrant, F.I.E.S.\*

A GENERATION may easily pass before an amenity, initially available only to a wealthy minority, can be said to be in general use. The rate of adoption depends largely on the character of the amenity and the social conditions of the time. To-day, the rate is very much faster than it was 50 years ago, having been influenced by the trend toward more equal incomes, by hire purchase, and by easier and more effective communication of ideas. But this eases only slightly the difficulty of setting down neatly a chronological review of domestic lighting. The subject is too wide—embracing the mansion and the cottage—and the period under consideration too recent for this survey to be anything but a "random review," and all dates must be considered elastic.

In 1908, when an experienced "cook-general" could be hired for £10 a year and a housemaid for £5, only the wealthy could afford electric light. Gas, oil and candles were in general use. Thus, the electrically lighted house was usually large, containing morning room, drawing room, dining room, billiard room, several bedrooms, nursery, kitchen and servants' quarters. In all probability, associated with it were a coach house and stables. The principal rooms were usually decorated in an elaborate and sombre style, with heavy durable furniture designed to give long service and, therefore, acting as a deterrent to change. The low reflection factors of the interiors and the low efficiency of the lamps then available demanded multi-lamp lighting fittings with minimum obstruction of light. The pipped vacuum lamps used projected well below the shades and were cantoned outwards. For lesser rooms and servants' quarters, however, the conical shade with a single lamp was considered adequate.

It is not surprising that most branch fittings followed the form of fittings previously used with candles, oil or gas. Some were good traditional patterns based on Georgian, Flemish or French styles, but many reflected the industrial revolution attitude to design with its ironwork and pipe-work.

After the introduction of the higher brightness tungsten lamp, and with the increased prosperity that preceded the first world war, many more homes were wired for electricity, and as people began to find the naked lamp distressing to look at, designers began using the lamps vertically and screening them within deep glass shades. The first totally-enclosed glass was probably the *flambeau*—a great favourite for the statuesque portable and newel fittings popular at the time. Then, two designs were introduced for use in particular rooms—the dining-room pendant, comprising a metal corona and silk flounce on a rise-and-fall device, and a dressing-table pendant with

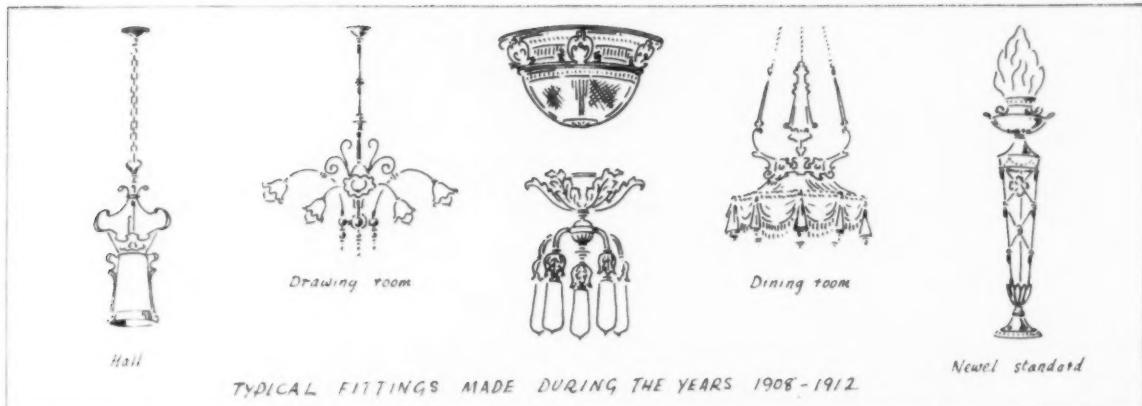
lamps at the extremities of a counter-weighted bar. The use of these fittings became virtually standard practice for about 20 years—a surprising length of time when one remembers how rapidly changes were taking place in the country generally and in the lighting industry in particular.

From 1913 to 1920, in spite of the war, there was a rapidly growing demand for cheaper fittings to keep up with the changeover from gas. Many three- and five-light pendant fittings were produced in forms similar to those of the gas units they were replacing. During the 1920s, however, this demand was greatly increased as vast schemes of "ribbon development" were carried out. Many thousands of new houses were being wired for electric lighting as a matter of course. The new type of householder wanted light with economy—preferably no more than one lamp per room, and the function of light as a component of decoration was, at that time, unrecognised or ignored. Large multi-light pendants, whether good or bad, did not meet the needs of this new mass market. The answer took the form of a comparatively high-wattage lamp suspended in an obscured glass bowl. As time went on the variety of these bowls became legion, from the simple blown hemisphere to elaborate shapes, equally elaborately decorated with line patterns or birds, beasts, fruit and foliage in several colours—handpainted or applied by transfer techniques. Pressed glassware, often very heavy, was also in use, and the more "refined" taste was satisfied by bowls of English or Italian alabaster. (It is interesting to recall that these bowls were the subject which brought the Electric Light Fittings Association into being in 1926.) The three chains by which the bowls were suspended were available in almost as many variations as the bowls themselves, with links of many shapes, and the total effect was heightened by using cord ornaments and husks on the central flex.

## A Conventional Arrangement

By the mid-twenties, lighting in the homes of the middle class observed a strict convention—a floured pendant in the dining room, an alabaster bowl or three-light branch fitting in the lounge, a twin-light pendant over the dressing-table in the bedroom, and a lantern in the hall. Most other points were equipped with flex drops with a small glass cone or shade. What is known to-day as the commercial enclosed type of unit now began to appear. It had a metal "gallery" with three screws holding a blown opal glass. Opal glass had, of course, been used as a diffusing medium for both oil and gas burners, but it was soon realised within the electrical industry that adequate diffusion could be obtained with a very thin glass,

\* The General Electric Co. Ltd.



thus giving greater efficiency. Such glass was, however, far too fragile for general use, and designers were faced with the problem of producing something more robust. The solution was a significant step forward; it comprised the production of a glass designed specifically for lighting—flashed opal. This glass, consisting of a thin layer of diffusing opal bonded to or sandwiched between sufficient clear glass to give the requisite mechanical strength, achieved a well deserved success, and is now in common use all over the world. A lipless version of the white flashed opal sphere was introduced on the Continent towards the end of the 1920s, and later found its way to the United Kingdom. With a metal downrod, this was another logical pattern which has remained virtually unchanged ever since, and is sold to-day in vast numbers, though mainly for non-domestic applications.

#### Fittings for the Wealthy

Concurrently with this trend toward utility and efficiency there was a substantial demand for fittings from wealthy people with large homes in the country. The motor car was by this time well established, public transport had improved beyond recognition and many people were moving away from the towns to the suburbs and the country areas. To meet the demands of the larger householders, whose tastes—although possibly simpler—were similar to those of their forefathers, large fittings of robust construction were designed. It was at this time, too, that fittings consisting largely of glass panels became established. Various types of glass were used, including heavily moulded satin-finished glass, though the most popular type was glass bent to shape, with the colour “fired” into it. Fittings of this type were, for the most part, elegant and distinctive. Furthermore, in no way could it be said that they were copies of fittings used in the gas industry. The use of etched lines on the glass panels provided effective and restrained ornament. In a few instances a note of over-severity crept in, and designers overcame this by using unusual metal treatments, typical of which was a rough-cast surface of oxidised silver, Grecian bronze, or old gold.

Development during the period from 1930 to 1939 was very mixed. The emphasis on the economy of current was diminishing steadily, if slowly, and the introduction of the coiled-coil lamp in 1933 made people increasingly aware of the discomfort of glare. Thus, in the better types of fitting there was a trend toward using more lamps of lower wattages, and even the bowl type of fitting was often equipped with three 40- or

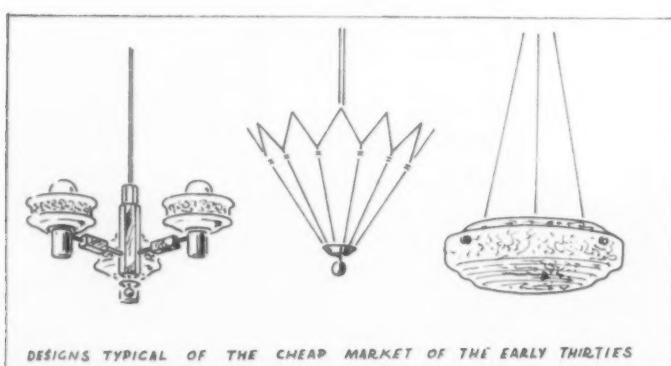
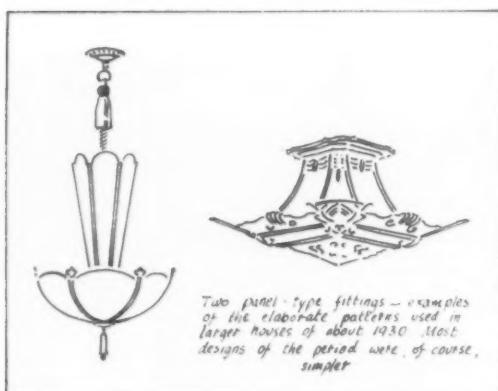
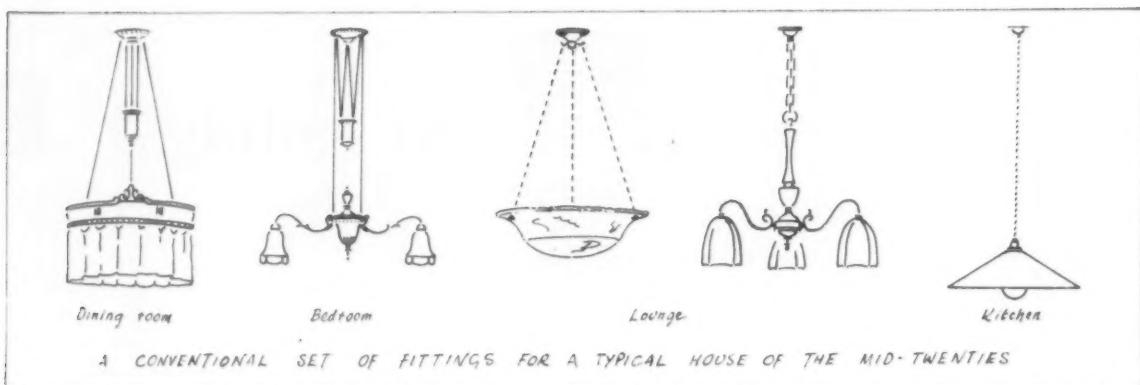


60-watt lamps instead of one 150- or 200-watt lamp. In particular, the “panel” type of fitting was used with several small lamps.

The market continued to expand at all levels. At the lower end flakestone bowls were joined by a multitude of cheap panel fittings of cut sheets of sprayed rimpled glass, clipped together simply and housing a single lamp. For better fittings, flashed opal glass was being used more and more.

**1910**

Middle-class  
drawing room,  
with multi-lamp  
fitting.



It was available in various colours and was decorated by etching, by sandblasting or by metallic lines of silver or gold. During this period chromium plate became a household word.

Encouraged, no doubt, by the lead given by some commercial undertakings, notably the "Corner Houses," which were using the "pulling power" of light to attract custom, there was among a section of the well-to-do a significant swing toward over-elaboration. "Built-in" lighting, appropriate enough for niches, bookcases, etc., was used widely without any real consideration of function or the aesthetics of the complete interior. Luminous door surrounds, beams, artificial windows and decorative panels were typical applications. At the same time there was a vogue for indirect lighting—the panacea for glare and the dispeller of gloom, hard shadows and other archi-

enemies of the lighting engineer. The monotony of the result was, however, accepted cheerfully or, more probably, not even noticed.

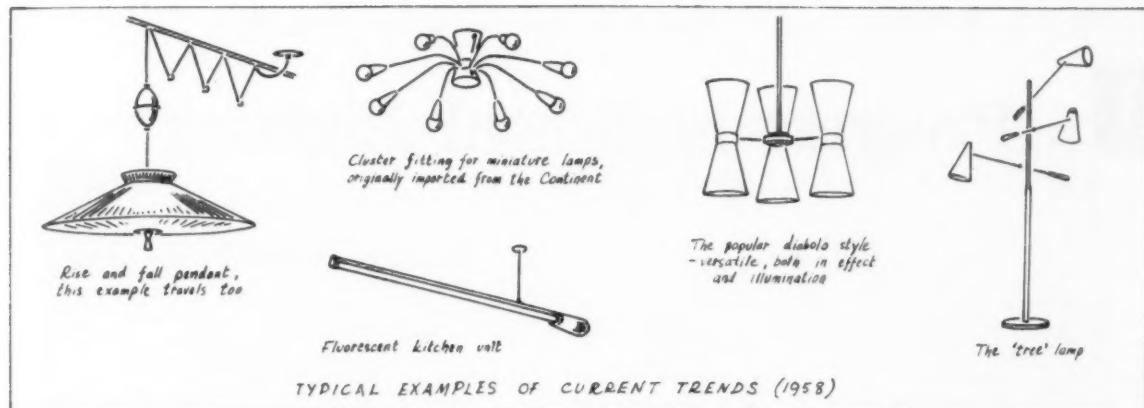
Leaving for a moment decorative fittings and "architectural lighting," it should be mentioned that a good deal of thought was being given to providing correct lighting in kitchens, bathrooms, etc. The reduction of glare, the positioning of the lights and the type of fitting were being considered, and a large choice of appropriate fittings became available. It is quite clear that by this time the use of electricity in the home was an established practice throughout the country, and it is worthy of mention that the number of manufacturers of lighting fittings had grown immensely. Although brass was still the usual basic metal, there were manufacturers specialising in wrought-iron fittings, in wooden fittings, and in shades made from a wide range of materials, from silk to cellulose. Plastic fittings, both British and imported, had come on to the market, and the public had a vast selection to choose from.

### The Late Thirties

Toward the end of the period (1930-1939) came the beginnings of the present "contemporary" style. While the "modernists" of the time, having banished ornament, were quite happy with their sterile designs, some architects were evolving a new style for interiors in which pattern and texture were again significant, but their ideas were offered to a mainly unresponsive public.

The second world war virtually halted progress in the decorative arts, but instead brought tremendous technological progress. The need for economy in time and materials, one result of which was the "Utility" furniture scheme, forced on the public a familiarity with unembellished good design far quicker than could ever have been achieved in peacetime. Immediately after the war, with the supply of materials still restricted, the pent-up demand for furnishings of all sorts was so great that practically everything that could be made could be sold. Through expediency, many manufacturers started where they had left off in 1939, and were so busy that little effort was made to produce anything more up-to-date.

The war, however, had brought about a second significant change. The fluorescent lamp had been widely adopted in industry and people had become accustomed to high levels of illumination. Many did not want to put up with an ill-lit home after a day in a well-lit factory or office. Electricity had remained reasonably cheap, and by 1950, partly because of the widespread use of high-



wattage domestic appliances, many people began to realise that the amount of current used for lighting did not seriously affect their electricity bill. Under the impact of television, magazines devoted to home furnishing, the rapid exchange of ideas internationally and the way in which light was being used in shops, restaurants, cinemas, theatres and exhibitions, the public became more conscious of lighting than ever before.

#### Post-war Trends

It would be beyond the scope of this article to describe in detail all the post-war trends in home lighting fittings, but attention should be drawn to the use of bold colours, a tendency toward lightness, more regard for shape, and the return to favour of "sparkle." Unfortunately, however, while following these trends, many fittings that have been produced have shapes that look pleasant enough on a drawing board but have little or no relation to the required lighting effect or to good mechanical and electrical engineering.

Without doubt we are living in an era during which domestic lighting is becoming more and more interesting. Our habits of living are changing, and our lighting requirements are changing too. Of particular significance is the now accepted use of several fittings in one room, in spite of the fact that in most rooms the wiring is still limited to one point in the centre of the ceiling with, perhaps, one outlet in the skirting. Ingenuity, adaptors and yards of trailing flex make the best of a bad job. The demand for adaptability, even under these conditions, is being met by devices such as "pin-up" brackets, travelling rails, ceiling pulleys, and crane-like brackets that can be adjusted both vertically and horizontally. At present such devices are more widely used in America than here in the United Kingdom, but they are bound to become more popular in Britain in the future.

The growth of the range of conventional table lamps and working lamps is helping toward the desired degree of adaptability, and floor standards now often have stems which support three or four reflectors, individually adjustable. The rise-and-fall device has come back into favour, now in the form of a neat spring-balance cord-absorber in a simple case. Formality in lighting fittings iswaning and an element of freedom and frivolity is creeping in. This may to some extent account for the comparative failure of the fluorescent lamp—so widely used elsewhere—to invade the British home. Its one great success is in the kitchen, where its characteristics make it an ideal light source.

For a new house, an intelligent owner now has almost unlimited possibilities before him. The cost may be more than some are willing to pay, but is, nevertheless, not excessive when compared with the amount that many people spend on other, less essential, items. In fact, one of the main reasons why standards of domestic lighting in the United Kingdom lag behind those on the Continent may well be that the public generally has yet to become accustomed to budget for lighting as an essential requisite of the furnishing scheme. The tendency is still to look on lighting fittings as something that can wait until all other items have been bought, and then purchased as cheaply as possible.

Most home-lighting requirements can be satisfied with no provision in the building structure other than correctly positioned outlets, but if one is prepared to go further, recessed fittings and spotlights now provide a convenient and unobtrusive method of providing light exactly where it is wanted, and for anyone who is concerned more with illumination levels than aesthetic effects complete luminous ceilings can now be bought as proprietary articles.

In conclusion, there now seems to be a sufficiently stable situation in the design of home furnishings to ensure the conditions under which a new style may emerge. This style will no doubt be in keeping with the twentieth century mode of living and outlook. It will call for lighting that is lively, versatile, and will permit changes without undue expense. Some further developments are inevitable, but history suggests that they will come slowly and almost imperceptibly.

#### 1955

**Living room of  
British show flat  
at Helsingborg  
Exhibition, (COID  
photo)**



## 3

# Progress in School Lighting

By J. A. Godfrey, A.R.I.B.A.\*

FIFTY years ago, the structure of public education as we understand it to-day was only just beginning to take shape. The Balfour Act of 1902 had abolished the local school boards and in their place the county, borough and urban district councils were made responsible for the development of all forms of national education.

The popular form of school layout at the beginning of this period was the central-hall type of plan which, in essentials, consisted of a large hall for general assembly with classrooms opening directly from it on two, three, or four sides. Many schools were built on this pattern, often on restricted town sites, and, to compensate for the high cost of the hall, they frequently had more than one storey. Despite its obvious disadvantages, the central-hall plan had the merit of compactness and was highly regarded by disciplinarians of the time because it facilitated supervision by the head teacher and the maintenance of discipline.

During the latter part of the 19th century, however, increasing attention was paid to the health of schoolchildren and in 1907 legislative action was taken to ensure that free medical inspection should be made available to all children attending public elementary schools. One result of this interest in children's health was that the central-hall plan began to lose favour, mainly because of the lack of good cross ventilation to the classrooms. In 1907 practical effect was given to this

view by the erection of an experimental school at Darlaston, Staffs, which had a row of classrooms with full-length openable windows on opposite sides.

Despite the emergence of more liberal ideas on school planning the approach to the daylighting of classrooms during this period seems to have been conditioned by rigid views on educational routine. These views called for a fixed layout of desks and seats, with the main windows to the left of the pupils. In other words, the type of daylighting provided by the standard classroom of the central-hall school.

The Building Regulations of the Board of Education relating to public elementary and secondary schools included rules for the lighting of teaching and other rooms. But, apart from stating that every part and corner of a school should be well lighted, these rules did not lay down any specific standards of daylight for elementary school classrooms, though they did include a recommendation on the maximum width of classrooms in relation to a particular window height. For secondary schools the rules were a little more specific and stated that the area of window glass for teaching rooms should approximate to one-fifth of the floor area and for other rooms should be not less than one-eighth. It was not possible at the time to define the desirable amount of daylight for classrooms with any more precision, as satisfactory methods of computing

\* Of the Building Research Station.



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School at Peckham Park.  
Gas installation still in use  
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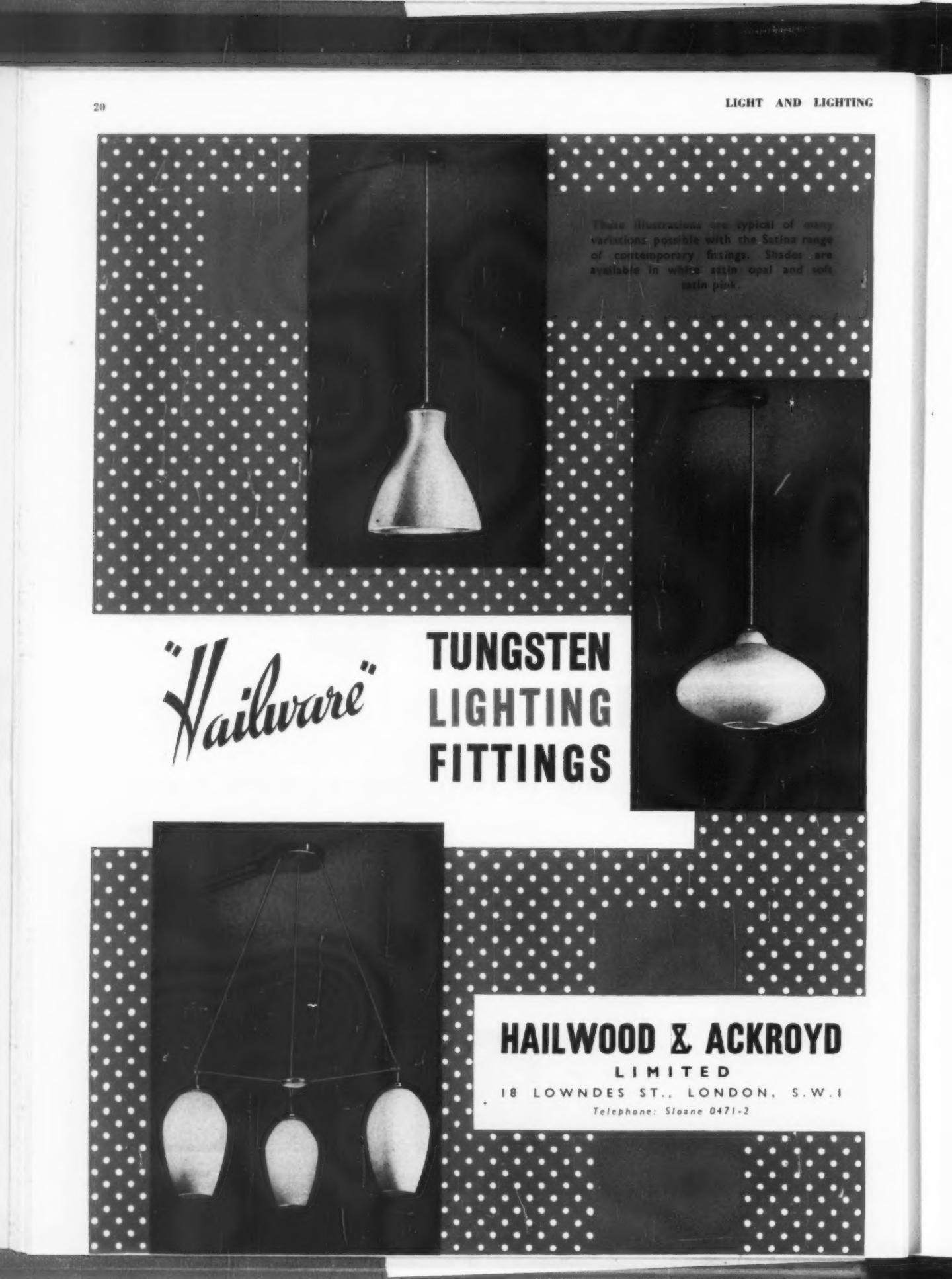


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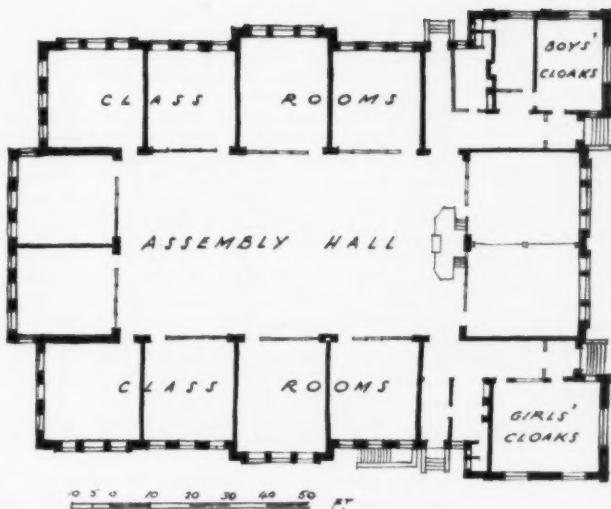
daylight levels had not yet been evolved. Much had already been written on the most desirable attributes of daylight in schools, and there was a general awareness of such practical considerations as the advantage of slender obstructions between windows and the bevelling of window jambs, but educational and architectural considerations usually took precedence over lighting considerations. Probably, the most definite requirement was the general insistence that windows should be placed to the left of scholars, though some cross light was not entirely ruled out and the Board's regulations did allow light from the right as the "next best." There was also some recognition of the part played by the colour of walls, ceilings and fittings, though in practice the choice of decorations seems often to have been dictated by considerations of utility rather than good lighting. For instance, green was generally regarded as the most satisfactory colour for the walls.

There was thus some regard for the factors which make for good lighting, but a real advance in lighting technique was not to come until many years later, when simple and precise methods for computing and measuring daylight were available to the building designer. An important step in this direction came with the publication in 1914 of the Interim Report on the Daylight Illumination of Schools prepared by the IES. Through the work of Waldrum and others it was then possible for the first time to suggest a minimum illumination level for school classrooms in terms of a daylight factor—namely, 0.5 per cent.

At the beginning of the period under review it was taken for granted that school classrooms would be lit by natural daylight and that artificial light would be used only for very short periods during winter when the daylight was insufficient. Gas was the main method of lighting and, at first, installations consisted of naked, flaring jets. With the rapid improvement in the power and efficiency of gas lighting the need for proper diffusion of the light by some form of shade or globe was soon recognised and, although the Board of Education did not include rules for artificial lighting in their Building Regulations of 1906, there seems to have been general acceptance of the view that unprotected lights should not be tolerated. One point of rather special interest is that an attempt was made to simulate the direction of daylight by placing the lamps over the desk area, slightly to the left of the pupils. It is also of interest to note that, although electric lighting soon became recognised as a useful and convenient alternative to gas, it was criticised at first for its insufficiency and for the adverse colour of the light.

### Early Progress

Between 1911 and 1914 artificial lighting for schools progressed rapidly and, as for daylight, attempts were made to lay down suitable standards of illumination. In 1911, N. Bishop Harman, lecturer in Ophthalmology for the London County Council Education Department, mentioned in *The Illuminating Engineer* the increasing demand for artificial lighting in schools with the extension of evening classes and suggested that the lowest possible illumination level for schoolchildren should be 1 lm/ft<sup>2</sup>. Later, in 1914, the Interim Report of the IES Joint Committee on the Artificial Lighting of Schools suggested a minimum illumination level of 2 lm/ft<sup>2</sup> for clerical work, 4 lm/ft<sup>2</sup> for special work, and 1 lm/ft<sup>2</sup> for assembly rooms, etc. The Committee also referred to the need for special blackboard lighting and suggested that this should be about 60 per cent. higher than that prevailing in the rest of the room.



### 1908-1914

Above, central-hall plan, much in favour at beginning of this period. Left, typical electric installation of the period.

After the First World War, the movement toward the more open type of school plan continued, receiving considerable impetus during the twenties from the schools designed by the Derbyshire County Architect, G. H. Widdows. The classrooms of these schools had glazed sliding-folding screens on the opposing-window walls, protected by open verandahs, while a large area of sloping clerestory lights on the north side provided the dominant daylight. Smaller clerestory lights on the south side gave access to direct sunlight. These schools were, in effect, the forerunners of the "open-air" schools, which reached their ultimate development in schools designed for tubercular children, where three sides of completely isolated classrooms were composed of sliding-folding glazed screens.

Some doubts were expressed at the time as to the possible bad effect on children's eyesight from lighting from two sides, but many schools with this form of daylighting were erected, so evidently the objections were not confirmed by experience. The writer has visited a number of the Derbyshire schools and found the daylighting to be excellent, even when viewed from the back of the classroom, where one would expect the bilateral light to be distracting. The reason is possibly to be found in the dominance of the large clerestory light and the reduction of the cross light from the sides by the roofs of the open corridors.

Throughout this period there were still many areas, especially urban ones, where the "open-air"

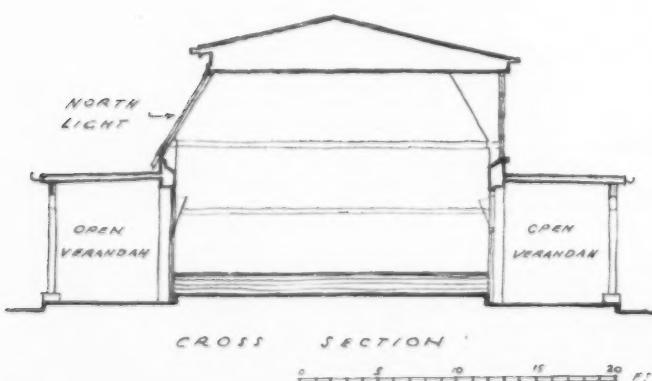
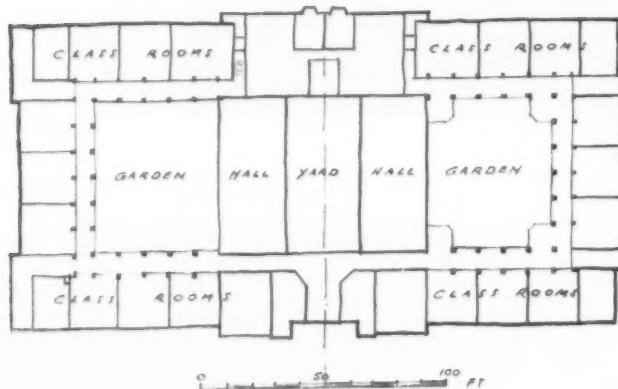
movement had few supporters. Some features were adopted, such as the open-sided corridor and a modified form of bilateral lighting, but in general the favourite type of layout was the quadrangle-type plan, either single or double. This form of plan was, in its time, as popular with some educationists as the central-hall schools had been before. Even so, it was the single-storey dispersed type of plan which, in 1938, received the official blessing of the Board of Education in its educational pamphlet on "Suggestions for the Planning of Buildings for Public Elementary Schools."

Despite the adoption of bilateral lighting for so many of the schools and the high level of daylight which resulted, it is interesting to note that the minimum daylight illumination recommended in the 1931 Report of the IES on the Natural Lighting of Schools still remained as recommended in the Interim Report of 1914—i.e., a daylight factor of 0.5 per cent. This figure was endorsed later in the Board's pamphlet mentioned above.

By contrast, as sources of artificial light improved in efficiency, there was a steady rise in the illumination levels recommended for artificial lighting. For instance, the 1931 IES Report on the Artificial Lighting of Schools suggested 5 lm/ft<sup>2</sup> for the lighting on desks; 8 lm/ft<sup>2</sup> for special work; and a minimum of 3 lm/ft<sup>2</sup> for assembly halls. By 1938 the minimum level suggested for most rooms had risen to 10 lm/ft<sup>2</sup>, while 8 lm/ft<sup>2</sup> was recommended for assembly halls. Where current was available, electric lighting was recognised as the most convenient source of light and a common form of fitting was the totally-enclosed opal

### 1918-1939

**Typical double-quadrangle arrangement : plan and section through one of the Derbyshire schools designed by G. H. Widdons in the '20s.**



sphere. Most of the recommendations for artificial lighting embodied suggestions for the appropriate diversity of illumination and for avoiding glare. In practice, however, the standard arrangement in classrooms was to place four units over the desk area, with supplementary lights for the teacher and for lighting the blackboard.

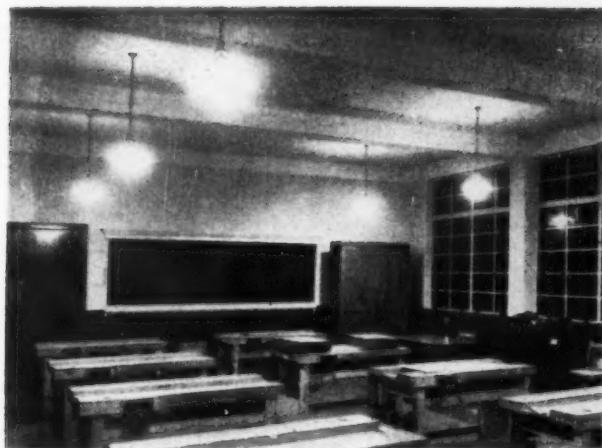
The Education Act of 1944 marked an important change in the development of public education. The Board of Education became a ministry and the local education authorities were reduced in number. The keynote of the 1944 Act was that every child should receive an education suited to his age, ability and aptitude. Another feature of the Act was the scope afforded for imaginative interpretation of its provisions by local education authorities. Along with this more enlightened attitude to education was a growing interest among architects in functional aspects of school design, including lighting, and this interest was undoubtedly stimulated by publications such as the Post-War Building Study on the Lighting of Buildings and the Codes of Practice sponsored by the Ministry of Works. Furthermore, the provision of such aids to functional design as the daylight-factor protractors devised by BRS made it possible for designers to estimate the daylighting of school rooms at the drawing-board stage with a degree of precision hitherto unknown except among a few specialists.

### Preoccupation with Daylight Levels

In the immediate post-war years, however, there appeared to be too great a preoccupation with levels of daylight to the exclusion of quality of the light. As a result of this rather narrow conception of the problem, there was a danger that the single-storey classroom with one large main window and a clerestory light above the corridor roof opposite would become as standardised in area and shape as the classrooms of 40 years ago, at a time when teaching methods were becoming free from the rigid ideas of the past. Some thought was given to the distribution of daylight and the gradient of illumination across classrooms and, as a result, several ingenious classroom profiles were produced. Some attempts were made also to deal with glare by providing external louvres and screens, as used in the well-known Californian schools and, later, by louvred blinds. All these expedients, however, were used rather arbitrarily and the main concern of most designers was to meet the statutory requirements of the Ministry's 1945 Building Regulations and the more exacting recommendations embodied in the accompanying Memorandum—i.e. daylight factors of 2 per cent. and 5 per cent., respectively, for teaching rooms.

### New Regulations

In 1949 a 25 per cent. reduction in the cost of schools was called for by the Ministry and the 1945 Building Regulations were withdrawn, being replaced two years later by a revised version which was less specific than its predecessor and allowed more scope for the architect to meet the changing views of educationists. The requirement for a minimum daylight factor was still set at 2 per cent., but the recommendations for artificial light included limitations on the surface brightness of lighting fittings and a general recommendation for the avoidance of excessive contrast in the field of view. The new regulations were followed by the Ministry's Building Bulletins Nos. 1 and 2, which dealt with the design of primary and secondary schools, and these bulletins were followed later by



**1918-1939**

**Two examples of use of totally-enclosed tungsten fittings during latter part of this period.**

others on cost studies, new colleges for further education, fire in schools, and the use of colour, and accounts of building projects carried out by the Ministry's Architectural Development Group.

Following the publication of the new Building Regulations, the emphasis, especially for primary schools, was on a more flexible use of windows than hitherto, in conjunction with novel room shapes to meet the more informal methods of teaching. Classrooms were planned in groups conveniently disposed round the assembly-hall/dining-hall unit, but not in the rigid formal pattern of the central-hall plan of 50 years before. Nor was the pattern as rigid as quadrigle layout or the straight blocks of classrooms of the immediate post-war years. The general abandonment of the straightforward rectangular classroom plan was probably the most significant change at this time. This emphasis on freer planning meant that designers could, to some extent, separate the functions of individual windows, redistributing them on various walls. Storey heights were reduced and simple forms of roof-light were often introduced to reinforce the light from the side windows.

A fairly recent development in school planning is the multi-storey classroom block with double-banked rooms. By skilfully using reflected light, it has been found possible to meet the statutory requirements with this arrangement, though it is

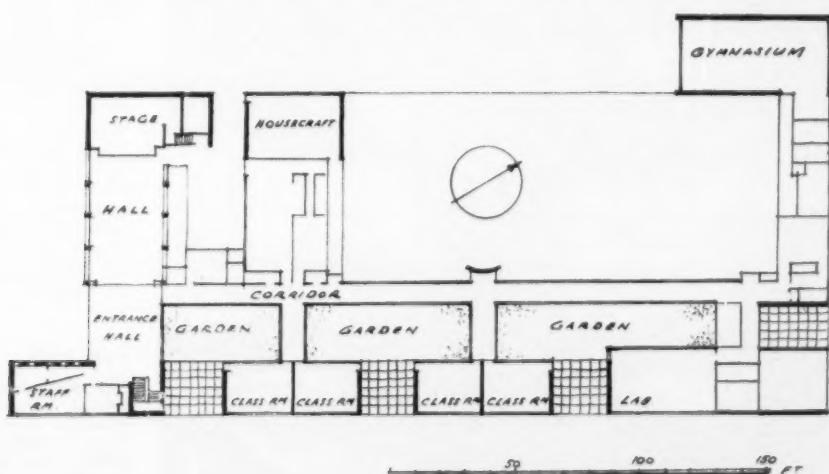


less easy to achieve a satisfactory visual environment. In some ways this development could be regarded as a swing of the pendulum back to the days of more compact planning, but with the essential difference that there is now a general awareness among designers of the part to be played by the decorations, especially since BRS has devised simple methods for estimating the effect of reflected light.

#### **Quality not Quantity**

The development of artificial lighting since the war has been in the direction of quality rather than any move towards higher levels of illumination, as seems to be the trend in American schools. In fact, the minimum levels of illumination specified in the original building regulations still stand at 10 lm/ft<sup>2</sup> for teaching rooms, this figure having been endorsed by the Joint Committee of the Medical Research Council and the Building Research Board when the 1951 Building Regulations were formulated. This figure is rather lower than the level of illumination recommended for classrooms in the IES Code, but it is a minimum and not a recommended level.

In the immediate post-war years there was a great deal of interest in fluorescent lighting but, apart from its use for special purposes—e.g. light-



**School in Richmond, Yorks, designed by Denis Clarke Hall, A.A.Dipl., F.R.I.B.A., showing the open form of plan which was becoming increasingly popular during the late '30s. Daylighting of the classrooms was almost completely bilateral.**



ing chalkboards and in workshops and gymnasias—there has been no general adoption of fluorescent lamps in new schools. The reason, no doubt, is that the limited demand for artificial light during the day in a school which receives plenty of daylight does not appear to justify the higher installation costs. For the relighting of old school buildings where the daylighting is below the statutory minimum there would appear to be a stronger economic case for the use of fluorescent lamps.

The present emphasis on multi-purpose classrooms and the lower ceiling height has encouraged designers to use small simple lighting units of the semi-direct diffusing type, adequate in number to provide good general light and with a surface brightness and cut-off designed to meet the requirements of the current Building Regulations.

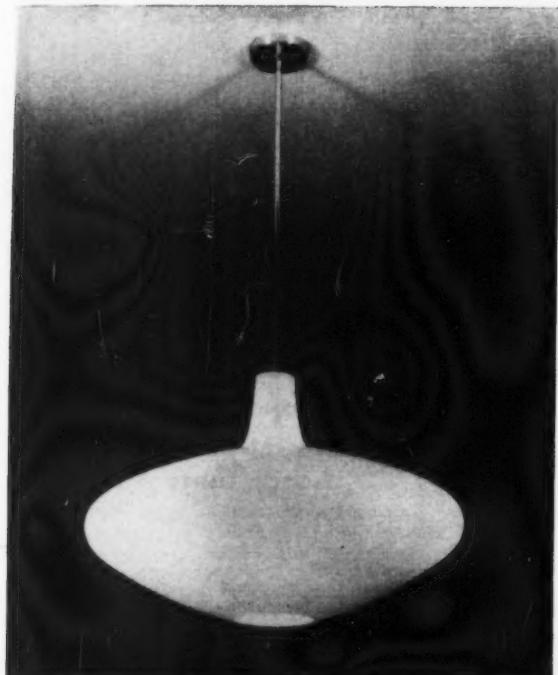
Another notable aspect of the development of school design since the 1944 Education Act is the bolder use of colours to enliven the architectural shapes. At first the aims of designers were not always clear but, in recent years, the increasing recognition of the close relation between lighting and decorations has placed this development on a sounder basis. It is true that the effect of light-coloured walls and other surfaces in contributing to the efficiency of the interior illumination has been known for many years, but the increasing efficiency of the sources themselves is placing the emphasis more on the apparent brightness relationships. In general, among school designers the trend is toward a more imaginative use of coloured and reflecting surfaces than hitherto. Since the war much research has been carried out on the methodical use of colour in building and a method of approach for the application of colour in school buildings based on this work is described in the Ministry's Building Bulletin No. 9, which was prepared by the Ministry's Development Group in close collaboration with the B.R.S.

Before attempting to hazard a guess as to the future development of school lighting it may be useful to sum up briefly the present position. From the beginning, the provision of daylight has tended to dominate the subject, though development in this direction was at first restricted by lack of technical knowledge and an inability to define standards exactly. Development was controlled also by the rigid ideas on educational routine, which tended to encourage the more inflexible types of school layout. Since 1945, daylighting technique has developed rapidly and there is now a more skilful use of windows and some regard for quality. The development of artificial lighting, too, was hampered at the beginning—mainly by a lack of power—and real advances came only when it was possible to define standards of illumination. Since 1945 advances have been made in providing good artificial lighting, but, in general, the advance has been modest because daylight is still the dominant element.

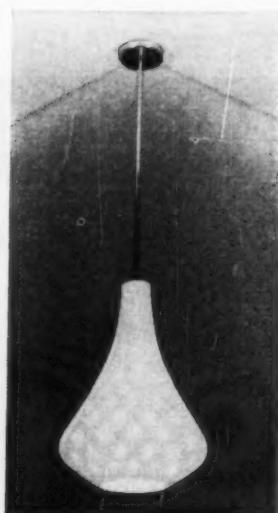
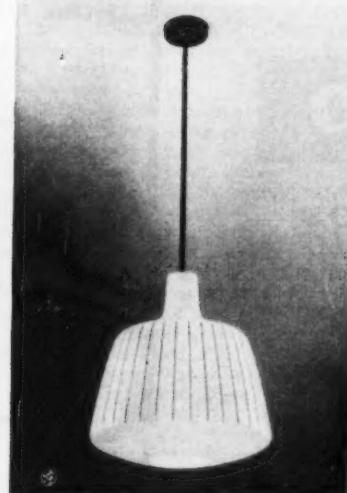
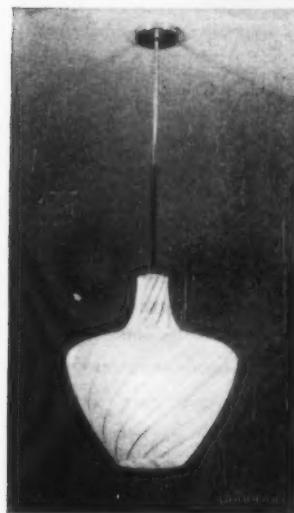
For the future, it seems doubtful whether daylight will cease to be of prime importance for most schools, but it is quite possible that a more skilful integration of artificial light and daylight will be achieved. One thing is certain, if the lighting of schools is to be satisfactory on all counts it will call for closer collaboration from the start between the lighting engineer and the architect.

#### 1944-1958

**Top, fluorescent lighting in an early post-war primary school. Left, classroom for 7-8 year olds in primary school at Amersham, Bucks. Light from standard tungsten fittings is supplemented by special pendant fittings near the windows. (Photo: "The Architects' Journal")**



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By H. Hewitt, A.M.I.E.E., F.I.E.S.\*

## 4 Lighting in the Office

**W**HEN the shorthand typist of to-day goes to her work each morning she has little idea of what the daily routine was like for the office worker 50 years ago. That worker was probably a man, and he probably travelled a shorter distance to a smaller and darker office. There he perched uncomfortably on a high stool, writing laboriously under lighting conditions which did little to assist his work. The office girl of to-day works faster, but she works under better conditions. Although her journey to the office may be longer and more arduous, she is likely to be more comfortable in the office itself.

This increased comfort and efficiency has been brought about partly by improvements in furniture design, the mechanisation of office procedures, and changes in building construction. But one of the most important influences has been the development of good lighting—both natural and artificial—which has created a general sense of well-being amongst office workers.

During the last 50 years commerce has developed greatly and, as a result, there are many more office workers. There has been also a trend toward the employment of more female workers, and this trend has probably added strength to demands for better working conditions. Nevertheless, some improvements in office conditions lagged behind the improvements made for factory workers. Immediately after the second world war factory lighting conditions were much improved, yet many office workers were still struggling in dismal surroundings. Since that time standards of office lighting have risen but much remains to be done.

As in many buildings, another factor which has influenced the lighting has been the growing standard of general education and, in particular, the growing appreciation by the public that good seeing conditions are essential to health.

### New Visual Tasks

Thus we find that four principal changes have taken place during the last 50 years: firstly, office workers are more numerous, secondly, there is a bigger proportion of female workers; thirdly, there is greater activity within the office; and, fourthly, there is a stronger desire (and even a demand) for better visual conditions.

Of course, the visual tasks in the office are very different from those which had to be lit in 1908. Although some typewriters were in use during the early years of the century, office mechanisation had barely commenced, and most workers were concerned with written words and written figures. Of necessity, this meant that the tasks performed were relatively slow and bore little relationship

to the more strenuous work of the modern office in which typewriters, comptometers, accounting machines and even computers are the main items of equipment. While these modern devices have speeded up the work greatly, they make exacting visual demands on the operators, and the development of office lighting technique during the last few years has had to take this trend into account.

The changes that have taken place, however, have not been concerned solely with office workers and the tasks they perform: office premises, too, have altered. In Britain's chief commercial towns and cities, office premises were, in the past, usually small and decorated in dark colours. Often they were virtually without daylight. In recent years, on the other hand, there has been a trend toward larger and more spacious general offices, and since the second world war a pronounced change has taken place in decorative ideas. New office buildings are usually planned with adequate fenestration and the problem of providing good artificial lighting is simplified by the light colours of the walls and ceilings. Moreover, there is often a sensible relationship between natural lighting and artificial lighting.

One additional factor should be mentioned: during the earlier years of the century the cost of electricity and of electric lamps was often considered as an important item in the running expenses of the office, whereas electricity to-day is a



An office of the 1920s lit by totally enclosed fittings housing tungsten lamps.



#### 1919-1939

**Top, office lighting scheme typical of the years 1925-1935, using two different types of totally-enclosed opal-glass fitting. Above, office lighting 25 years ago, with open-bottomed prismatic glass fittings.**

relatively cheap commodity and most employers recognise that expenditure on good artificial lighting is a sound investment.

During the period under review lighting engineers have had to adapt their ideas on office lighting according to changes in the composition of office staffs, in the nature of the jobs they do, in the equipment they use, and in the buildings in which they work. Nevertheless, a study of the subject indicates that certain basic problems have been present throughout the period, for as the years have passed successive attempts have been made to increase illumination levels and to reduce glare, contrast and unwanted reflections.

In 1908 electricity was struggling to oust gas as the fuel for office lighting, and this struggle was to continue for many years. Already, however, electricity was achieving some success, and one of the reasons for this success was probably that electric sources lent themselves more readily to localised lighting.

In the first volume of *The Illuminating Engineer* an illustration was published which shows all too clearly the excessive contrast caused by the use of localised lighting in the office. Such lighting was criticised at the time by Dr. Louis Bell, who wrote, "No artificial light should be arranged so that it forces the eye to make sudden transitions from blackness to brilliancy." These uncomfortable contrasts were overcome by a trend toward more general lighting, particularly in the larger offices, and by 1911 it was even possible to find examples of totally indirect lighting schemes.

However, the pendulum swung with a vengeance, and some indirect lighting schemes of the period must have given offices a flat and dismal appearance. At a time when source efficiency was low and the reflectivity of decorations was usually poor, indirect lighting in offices cannot have been satisfactory. Lighting engineers were, however, aware of this difficulty and in 1912 Leon Gaster designed a semi-indirect scheme for his own office which seems to have set the pattern for general office lighting for all time, for if any of the five classical lighting "systems" are to be recommended for office lighting, one must surely choose the semi-indirect or the semi-direct.

#### Rapid Developments

At the time when Gaster's own office was relighted, lighting engineers were much concerned with office lighting. This was an era of fairly rapid development in incandescent lamps, and new lamps were often used in old fittings, sometimes with disastrous results. By the year 1919 we find that Mr. Wise was summarising the trends of the day in a paper ("Modern Practice in Office Lighting") in which he recommended an illumination level of  $4.6 \text{ lm}/\text{ft}^2$  as satisfactory for general office work, and pleaded for a reasonable relationship between general and local lighting. He pointed out the need to avoid glare and undue contrast and also the undesirability of disturbing reflections and shadows. We find, moreover, that Mr. Wise was concerned with the detailed positioning of light sources in relation to desks, typewriters, etc., and that he was calling for a change to lighter colours and matt surfaces in the decoration of the office.

By the 1920s the provision of lighting equipment for the office was not always an afterthought and serious attempts were being made to plan office lighting scientifically. In 1922 Rayner, Walsh and Buckley reported on an investigation into various systems of general office lighting carried out at the Ministry of Pensions' building in Acton. It is significant that the basis of these experiments

was a system of semi-indirect lighting using opal bowl fittings. Many experiments were made with lamps of different wattages—in different formations and with various decorative schemes. As a result of the investigation it was decided finally to adopt the following system: fittings with 14-in. bowls were equipped with 200-watt lamps, the walls being painted light buff, with a reflection factor of 60 per cent, and the ceiling being white with a reflection factor of 80 per cent. This was the pattern of general office lighting that was to continue for some years, except that there was a trend towards totally-enclosed fittings—a trend that was caused by the high cost of servicing open bowl fittings.

#### Advantages of Fluorescent Lamps

Between the mid-thirties and the outbreak of the second world war there were few changes in office lighting, except for a gradual increase in illumination levels, but since the end of the war we have, of course, seen a major revolution in office lighting. This revolution has been the result of the advent of the fluorescent tubular lamp. During the years when only the daylight variety was available, fluorescent lamps were used mainly in factories and there were few office installations. However, with the coming of the warmer colours, management were quick to see the advantages of fluorescent lighting in providing high levels of illumination combined with good quality of light.

At first, of course, the fluorescent lamps were used in standard industrial reflectors (see below), but it was soon realised that these fittings were not suitable for most office interiors. Moreover, as the growing use of fluorescent lamps coincided with the change to lighter colours for decorative schemes, fittings giving a generally diffuse distribution were called for. At this time, the use of acrylic plastics for lighting fittings was being pursued, and an early type of office fitting which set the pattern for some years to come is illustrated below right, where the fitting can be seen both ceiling-mounted and suspended.

In contrast to the slow progress in incandescent lighting between 1907 and 1937, progress during the "fluorescent era" has been rapid. The fluores-

cent tubular lamp was soon accepted as the most appropriate light source for new offices, and it was found particularly valuable for the lighting of drawing offices, for which, in the past, some form of local lighting had nearly always been unavoidable. Some difficulties arose at first because of shadows thrown by instruments, straight edges, etc., but these were soon overcome when the fittings were carefully orientated.

The post-war years brought with them rapid developments in building technique and the popularity of the false ceiling was responsible for a trend toward built-in lighting. This trend manifested itself in various types of building and soon influenced office lighting. Recessed fittings were developed, some designed to fit into proprietary suspended ceiling systems, and their use developed rapidly. However, as levels of illumination were raised the problem of the control of glare became more serious and lighting engineers turned to various types of louvre for their solution. As an alternative, the completely illuminated ceiling was developed. While the use of a light source of large area is not acceptable in all buildings, the reduction of shadows in offices is of such prime importance that, even if there is a lack of modelling, this disadvantage may not be considered serious if shadows are successfully eliminated.

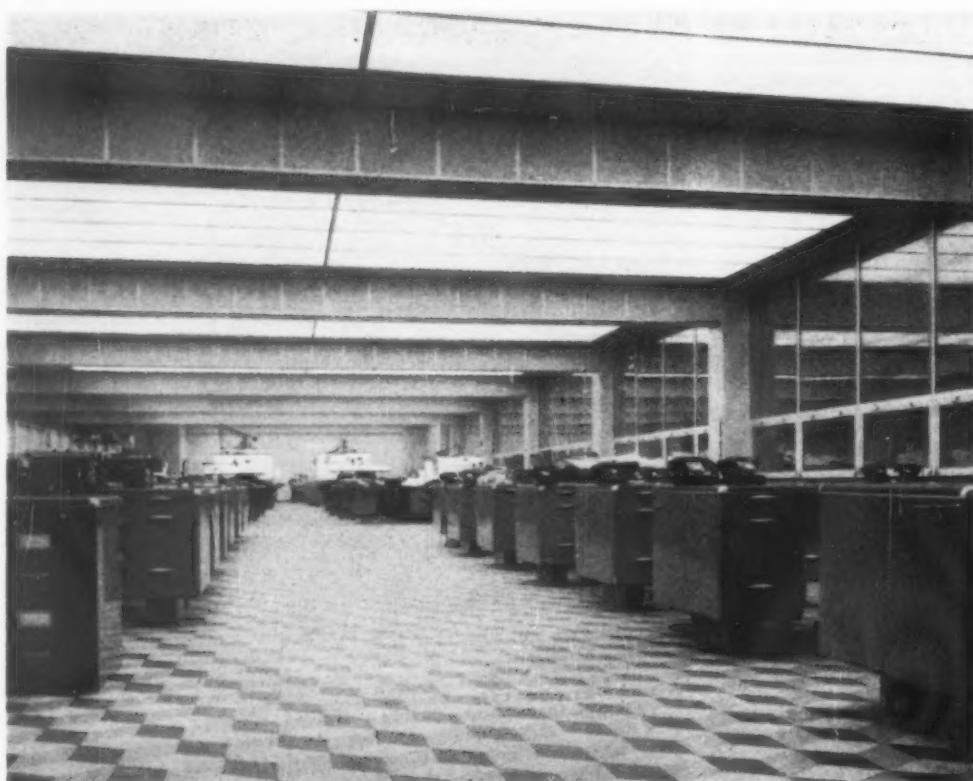
#### Conclusions

Comparing the first and the last photograph of those accompanying this article alone gives some indication of the progress in office lighting during the last 50 years. This progress has undoubtedly contributed to higher efficiency and to greater well-being amongst office workers. An illumination level of 15 to 20 lm/ft<sup>2</sup>, which would have been thought extravagant even a few years ago, is now commonplace, and this improvement in quantity has generally been accompanied by an improvement in quality. But office lighting still remains a challenge to the lighting engineer, for in offices not only are some of the most difficult visual tasks carried out, but the lighting engineer must take into account the complex office routines and office systems which affect his scheme, a careful study of which must be made before he can be sure of solving his problems.

#### 1945-1958

**Left,** early post-war installation using industrial-type fluorescent fittings. **Right,** fluorescent lamps in fittings with acrylic plastic diffusing covers.





#### LIGHTING IN THE OFFICE

1945-1958

Top, office lighting by means of luminous ceiling of vinyl sheeting concealing rows of fluorescent lamps. Left, lighting of drawing office by fluorescent lamps and fittings arranged to minimise shadows.

By A. H. Olson, B.Sc., A.C.G.I., M.I.E.E.\*

## 5 The Development of Shop Lighting

SINCE time immemorial Man has traded with place in open markets. The Assyrians, the Egyptians, the Greeks and the early Romans all utilised the open market, where nothing more elaborate than a temporary booth or stall was used to house the wares. It was not until the 13th century, when trading had begun to take place indoors, that artificial lighting may have been used in connection with trading—albeit in a very minor role.

With the industrial revolution came a great flow of goods, a redistribution of population—toward the towns—and easy methods of transportation and travel. As a result, shops began to develop. The advancement of science brought with it better light sources, and these, coupled with the advent of street lighting, which made streets safe for pedestrians after dark, extended shopping hours. This development led to the use of the illuminated window in which merchandise was displayed after the shop closed.

Thus, retail premises began to take on a personal character and, with the wider range of goods that became available and the improvement in living standards, shops prospered and some merged, leading to the growth of the stores as we know them to-day.

Throughout the expansion, artificial light by gas and electricity had begun to assume its role. From

### 1908-1920

Left, shoe shop in 1908. Note window lighting from fittings outside. (Compare with photograph on page 35.) Right, a men's outfitters in 1909.

\* Courtney, Pope (Electrical) Ltd.

small beginnings it became the primary tool of the retail trade.

In 1909 shops were lit mainly by gas, carbon arc or filament lamps, and it was at this period that a cheap process for the manufacture of tungsten filament lamps was introduced, making the use of this lamp a commercial proposition.

During the early part of the century shops were lit by heavily ornamented fittings with open-bottom reflectors giving, as a general rule, about  $3 \text{ lm}/\text{ft}^2$ . The lighting was used primarily to enable the customer and the shopkeeper to see the merchandise which was distributed around the shop as in a stock-room. It is interesting to note from Leon Gaster's and J. S. Dow's book, "Modern Illuminants and Illuminating Engineering," published in 1915, that illumination levels of 3 to  $10 \text{ lm}/\text{ft}^2$  were being recommended.

### Lighting Outside the Shop

External lighting was fairly general, many shops having carbon arc or gas lights shining into the windows and lighting the pavement in front of the shop. Illuminated signs were beginning to be in evidence and, in general, they were constructed from glass, with the letters etched into or painted on to them.

During the years immediately after the first world war the struggle between gas and electri-





city was intensified and, with the achievement of ascendancy by the latter, lighting became a science instead of just a menial service.

Twenty-five years later, shops and stores were hardly recognisable from those of 1909. The expansion of trade and the redistribution of population and wealth resulting from the first world war had seen the growth of larger stores, while the "speciality shop" began to make its appearance.

Shops had to fight for their existence and, to apply fresh thought to changed marketing ideas of retailing, architects were called in.

Their new ideas, when applied to store planning, resulted in the gradual introduction of the open front; increased flexibility; the end of large arcades for windows; and a gradual development of the role of display and supplementary lighting, hinting at the part it was to play in future years.

The tungsten lamp had come into its own, and with its high efficiency and low cost, was the main light source for shops, cold cathode being used in coves for indirect lighting and for external signs. Windows were lit entirely by tungsten lamps, usually of sizes larger than 100-watt, in mirrored angle troughs or angle fittings. The fittings were usually concealed behind the pelmet, giving illumination levels of up to  $50 \text{ lm}/\text{ft}^2$ .

For interiors, large tungsten lamps or clusters of smaller lamps were incorporated in enclosed glass fittings, giving illumination levels of about  $10 \text{ lm}/\text{ft}^2$  or more. As a result, the lighting fittings were generally the brightest points of the sales floor.

#### The Second World War

During the years immediately after the second world war lighting developments were drastically curtailed—it was a period of shortages of materials, manpower and electrical power. Window lighting was not allowed for some time, and interior lighting was limited to  $1.5 \text{ W}/\text{ft}^2$  for selling areas, while building licences and other restrictions all hampered the growth of lighting. Fluorescent lamps, if used at all, were used bare and connected to existing points, and levels of  $10-15 \text{ lm}/\text{ft}^2$  were average.

With the gradual removal of restrictions, however, store planning developed. New stores were built in the bombed towns and cities, such as Coventry, Hull and Bristol, and existing stores were modernised. Speciality shops, in particular, profiting from experience in the United States, began to use eggcrate ceilings, luminous panels, modular-sized built-in lighting units and interchangeable lighting panels. Fluorescent lamps began to be enclosed in glass, plastic and pierced metal screens and, with the development of display lighting, new installations combining mixtures of fluorescent and tungsten became common.

Recently, another stage has been reached in the lighting of shops and stores. The emphasis on lighting has now turned from "lighting for seeing" to "lighting for selling," with the main accent on the merchandise. The main differences between our present stores and those of the past are colour, *décor* and flexibility of display, aided by higher levels of illumination. The emphasis is

#### 1920-1939

**Top:** Davies of Holloway Rd. in 1920;  
**centre:** floodlighting of Jones and Knights,  
**West Ealing,** in the early 1930s;  
**bottom:** Bobby's of Folkestone (1936).



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on display lighting integrated with flexible displays, with a corresponding reduction in brightness contrasts.

The introduction and development of the fluorescent lamp has been used by shopkeepers to meet competition, and levels of illumination have been raised to between 20 and 50 lm/ft<sup>2</sup>, depending on the type of store. Ceilings of interchangeable panels or large translucent areas can be lit easily and efficiently by fluorescent lamps and these lamps have, therefore, become very popular for general lighting, while display lighting is provided by internally silvered tungsten spotlights. The display lighting is now integrated with shop fixtures and illumination levels achieved are higher than those given by the general lighting. Perimeter lighting concealed by a valance or by pelmets has also become popular. It lights the merchandise and, at the same time, reduces the brightness contrast.

High levels of illumination have made it imperative to reduce brightness contrasts for visual comfort, with the consequence that the store designer has introduced a large number of illuminated fixtures, such as shadow boxes and translucent backgrounds, all tending to give a lively atmosphere to the sales area, as well as displaying the merchandise attractively. The quality

of light and colour now expected requires careful understanding and the integration of design at the initial stages, particularly when merchandise is to be lit by coloured sources or when the merchandise is to be displayed in front of a coloured background, is essential.

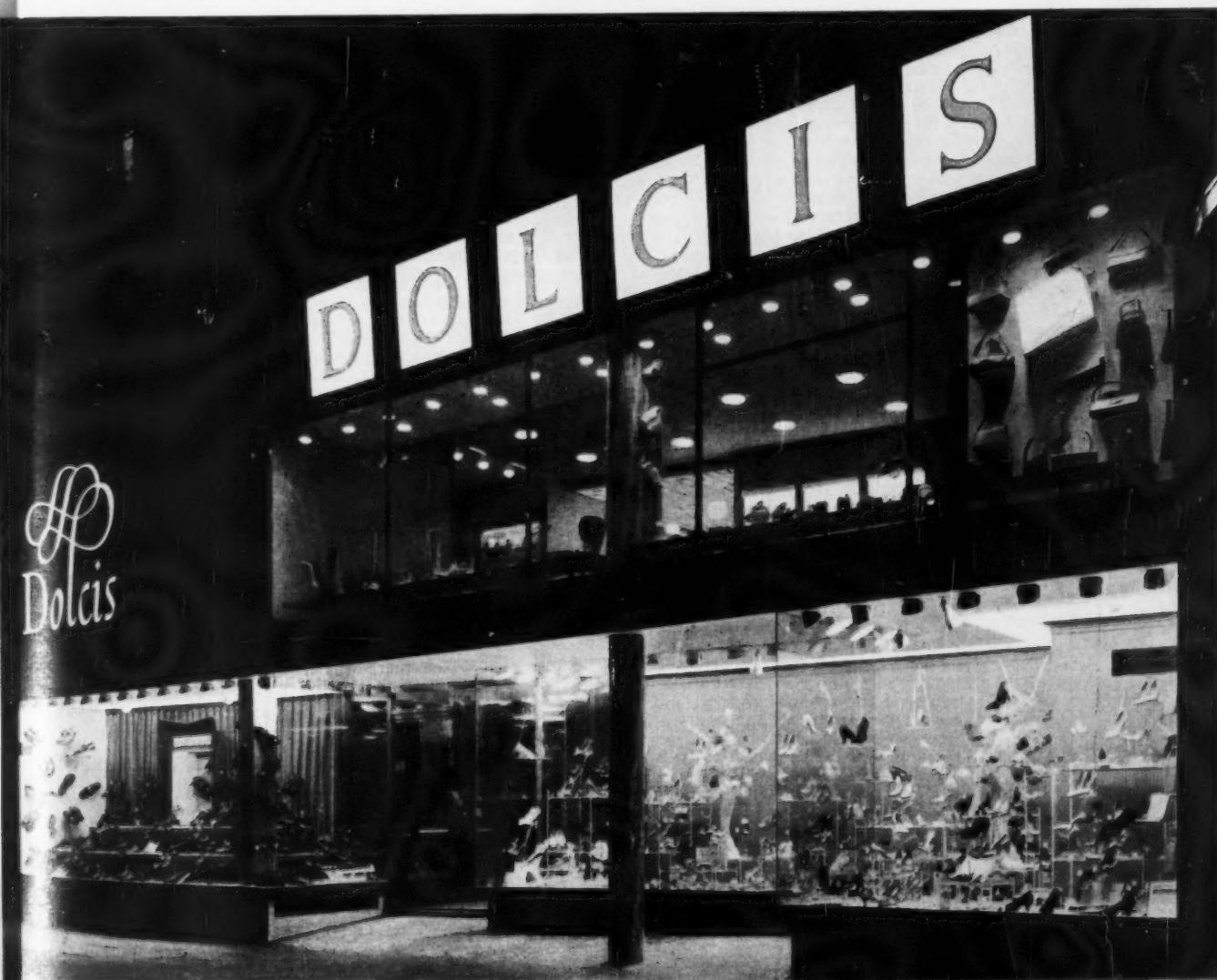
The appropriate quality of light for the merchandise is now most important, and it is becoming common for general and background lighting with fluorescent lamps, and display lighting with tungsten lamps, to be co-ordinated with the colour scheme and the *décor*.

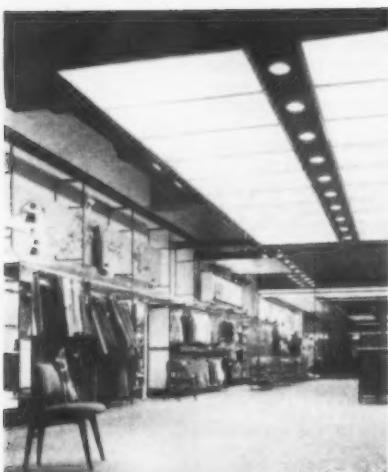
For shop windows, while the dimensions, the general design and the type of shop largely determine the method of lighting, there have been trends toward the combination of fluorescent and tungsten light sources; the provision of higher levels of illumination; the use of background lighting; the concealment of light sources and the achievement of greater flexibility.

Tungsten lighting by means of internally silvered reflector spots is usually used for emphasis on the merchandise, while fluorescent lamps are mainly used for the general lighting of the windows and for background lighting. Coloured lighting of backgrounds offers a further contrast between merchandise and setting. The use of wiring channels, baffles, "picture frames" and louvres, are

1957

A modern shoe shop : Dolcis, Charing Cross Road.





some of the methods that can give flexibility and assist in concealing the light sources.

The problem of window reflection from glass is still unsolved and, while curved glass windows are now out of favour, attempts at slanted glass fronts have provided some interesting new designs.

In general, the aim to be "different" has led to practically every lighting method being used to light some shop or special display area, with the result that sound lighting practice has become widely accepted in the design of the retail store.

What of the future? With the new materials and equipment that are becoming available, it seems likely that it will be possible to design shops of shapes and sizes not hampered by any structural considerations. With improved contacts between one country and another, the architecture of the whole world can easily be assimilated, so that new ideas can constantly be used to meet the demands of the shopping public.

Lighting will surely remain one of the main

aids to selling, and new light sources will no doubt appear, providing even greater light outputs and more flexible tools for the designer to use in the ever-changing pattern of architecture.

On the outside of the building the lighting may be required to create a new "luminous" after-dark appearance. Competition will, no doubt, force illumination levels even higher; air conditioning may be integrated with lighting design; and problems of lighting contrast will probably be more easily solved by the use of the electroluminescence light source. Replacing tungsten and fluorescent lamps, with their physical limitations, the application of this new light source to large surface areas could completely alter the existing conception of general and background lighting in the retail store. Its greater potential efficiency, quoted by leading authorities in the United States as 200 lm/W, suggests countless applications and opens up new horizons for the architectural use of light.

#### 1945-1958

**Three modern shops. From left to right:** Richard Shops, Oxford St. (luminous ceiling and spotlights); Owen Owen store, Coventry (surface-mounted fluorescent fittings); Landport Drapery Bazaar, Portsmouth (down-lights and spotlights).

## 6 Industrial lighting

By H. C. Weston, F.I.E.S.

**A**T the time this story opens many of the "dark satanic mills" of which the poet Blake wrote in the nineteenth century were still in use. They were badly designed as to natural lighting, ill-equipped for artificial lighting and forbidding in appearance—both without and within. But there were new factories then, as there are now, and some of these made excellent use of natural lighting when it was available. Nevertheless, on the whole, the state of industrial lighting in 1908 left much to be desired, and it was not long before the Home Secretary thought it necessary to appoint a Departmental Committee to inquire into it and to make recommendations.

The normal working day was then at least 10 hours and sometimes longer. Work began at

6 a.m. and finished at 5.30 p.m.—when there was no overtime. Thus, the amount of working time in which there was dependence on the artificial lighting of the period was substantially greater for day shifts than it is now, or than it was even in the second decade of our story, when the 48-hr. working week was generally adopted. The writer's own experience of factories goes back to those "bad" old days when one turned out at 5 a.m.—seemingly the middle of the night in winter—so as to clock-in at 6 a.m. and then spent the ensuing 11½ hrs. in, or in the precincts of, the dreary "works."

Gas was a widely used illuminant but the use of electricity was spreading. The candle itself had not yet been entirely ousted as a local light

### 1913-1914

**Records of illumination levels made by the Home Office Departmental Committee.** 1, 2, 8, spinning and weaving; 3, 6, hosiery and lace; 9, 10, clothing; 1, 4, 5, 7, engineering. Range of mid-values shown between arrows.

source, nor, indeed, was it to be for some time to come. Most of the large factories which had electric lighting generated their own supply. Supply companies were not able to offer particularly attractive terms to factory consumers who required only a supply of energy for lighting for a few hours each day when the load was at its peak.

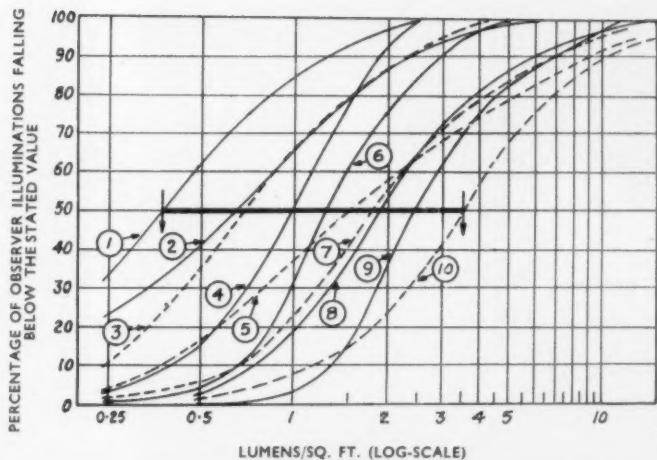
For artificial lighting the accent was on economy in the most direct and superficial sense. The cost of artificial lighting was considered a necessary evil and there was, as yet, no general appreciation that bad lighting might really be more costly than good lighting. Many installations, particularly in the smaller factories and workshops, consisted of small sources irregularly disposed according to the situation of benches and individual machines where as much as possible of the meagre supply of light was plainly needed. General or "space" lighting was often merely incidental or—it might almost be said—accidental.

#### Other Light Sources

Things were better in some of the larger and loftier factories, where fairly good space lighting was provided by means of suitably spaced flame arcs. Of other electric light sources, carbon filament lamps were common, though metal filament lamps were gaining ground and continued to do so after the introduction, in 1909, of lamps with drawn tungsten-wire filaments. In this first decade of the period under review, mercury-vapour lamps were also in use and, for processes demanding good colour rendering, "lamps of the pure white, daylight effect, as those made under 'Carbone' patents," were available, instead of the more usual flame arcs using impregnated carbons. For gas lighting incandescent mantles were in general use, though "fish-tail" or "bats-wing" burners were still common and remained so in some workshops for a number of years.

As to levels of illumination, an authoritative contributor writing in the first number of this journal remarked that "the general demand for all purposes is in the neighbourhood of four to six times as much light as was considered sufficient within the recollection of middle-aged people." Bearing this in mind, the values of illumination disclosed by the most reliable records obtained in the first five or six years of our history suggest how very inadequate factory lighting must have been in the "naughty nineties." The records referred to were made during the winter of 1913-1914 for the Home Office Departmental Committee on Lighting in Factories and Workshops and published in the first report of this committee made in 1915. They consisted of photometric observations made in representative factories in the engineering, textile and clothing industries by Mr. (now Dr.) J. W. T. Walsh and Mr. G. F. Sedgwick, an Assistant Factory Inspector.

Measurements of the illumination at floor level—which are indicative of the "space" lighting—ranged from less than  $0.1 \text{ lm}/\text{ft}^2$  to more than  $2 \text{ lm}/\text{ft}^2$ , with a mid-point (i.e., the value above and below which lie equal numbers of the other measured values) of  $0.5 \text{ lm}/\text{ft}^2$  for all factories except foundries; in the latter, the mid-



point value was  $0.4 \text{ lm}/\text{ft}^2$ . In weaving sheds the most frequently measured illumination on the cloth was about  $1 \text{ lm}/\text{ft}^2$ , though the observations were distributed about a mid-point of  $2 \text{ lm}/\text{ft}^2$ . Two per cent. of the total number of observations exceeded  $10 \text{ lm}/\text{ft}^2$ , but a much larger percentage fell below  $1 \text{ lm}/\text{ft}^2$ .

In spinning mills more than 60 per cent. of the measurements at the mules were below  $0.5 \text{ lm}/\text{ft}^2$  and the mid-point value at other machines was only  $0.6 \text{ lm}/\text{ft}^2$ . In lace- and hosiery-making the mid-point for lace machines was  $0.7 \text{ lm}/\text{ft}^2$ , though for hosiery machines this value was nearly doubled. In engineering shops the mid-point illumination level for machine work was  $1.6 \text{ lm}/\text{ft}^2$ ; for bench work it was  $1.85 \text{ lm}/\text{ft}^2$  and for heavy work it was  $1 \text{ lm}/\text{ft}^2$ . Clothing factories made a somewhat better showing. The mid-point for sewing on coloured materials was  $3.6 \text{ lm}/\text{ft}^2$  and for white materials,  $2.5 \text{ lm}/\text{ft}^2$ . Less illumination was used for cutting and pressing.

The great war of 1914-1918 began a few months after this survey of contemporary industrial lighting was made. "The lights are going out all over Europe" said the Foreign Secretary of the day as this tragedy unfolded. But they could not go out in the factories where prolonged

### 1915

**Electric lighting in leather-dressing works.**



## GAS

**Gas-lighting installation in engineering shops during the 1920s.**

and strenuous efforts were needed to produce the munitions of war. Nevertheless, scant attention was given to the improvement of factory lighting, though as the war progressed the investigations of the Health of Munition Workers Committee led this body to point out, in a Memorandum published in 1916, the need for better conditions. Attention was drawn also to the serious loss of daylight due to dirty factory windows, a loss which was accentuated by "the anti-air raid darkening regulations." But, besides low values of illumination, other conditions of artificial lighting were known to be unsatisfactory at this time. Glare was extremely prevalent owing to inadequate screening of light sources and to the use of direct lighting by clear lamps for work with specular materials. Complaints of dazzle and of "eyestrain" were common, but usually ineffectual.

### "Fit for Heroes to Work in"

When the war ended in 1918 there were high hopes of rapid progress towards a Utopia. Britain was to be "a land fit for heroes to live in." Having, at least partly, shattered the former "sorry scheme of things" it was now to be rebuilt "nearer to the heart's desire." But many of these hopes were not to be fulfilled quickly, and better factory lighting was certainly slow in coming. There was, however, some organised attempt to find out what the conditions of lighting ought to be in the interests of the workers' health and efficiency. The Industrial Fatigue Research Board, which was set up in 1918, proceeded to study, *inter alia*, the effects of conditions of lighting in industry. By 1922 four reports by the present writer and his co-investigators, S. Wyatt and E. J. Elton, had been published. They showed how efficiency in different branches of the textiles industry varied with illumination levels. They showed also that the levels revealed by the 1913-1914 survey still prevailed. In 1920 the Departmental Committee on Factory Lighting resumed its work and, with J. W. T. Walsh and the writer as joint secretaries, the committee made its second report in 1921 and its third in 1922. But its modest recommendations could not be translated into regulations without a new Factories Act, and nearly two decades were to elapse before statutory factory-lighting regulations were made.

As soon after the Great War as the summer of 1920 an industrial depression set in with unexampled suddenness. The 48-hour working week had already been introduced, thus curtailing to some extent the use of artificial lighting in factories. Now, however, unemployment and short-time working became prevalent. So the duration of artificial lighting in factories was still further reduced and the workers were in no position to press for improved conditions. Employers could not afford either the capital cost of relighting or the increase in "overheads" which more humane standards of lighting were assumed to entail. As this state of affairs continued for several years, factory lighting generally was not noticeably enhanced during this period.

Nevertheless, the need for more knowledge of industrial lighting requirements having been stressed by the Factory Lighting Committee, and an Illumination Research Committee having been set up by DSIR, further investigations were initiated. Thus, in 1926, the results were published of an experimental investigation by the writer and A. K. Taylor, of the NPL, which showed the relationship between illumination levels and the efficiency of hand compositors. It appeared that the desirable illumination for this and other visually comparable work is  $20 \text{ lm}/\text{ft}^2$  or more, whereas it was at that time a common practice to provide considerably lower values in composing rooms. This was the kind of demonstration likely to interest factory occupiers in providing better lighting, as it showed that improvement was good economics and not merely humanitarianism. The lighting industry was not slow to make use of these findings as evidence supporting its advocacy of more liberal lighting in factories and, with a lessening of the industrial depression (coupled with a falling cost of lighting per unit of illumination), sporadic advances in lighting practice in factories occurred.

### A Notable Decade

The third decade of the half-century under review was notable in several ways. There was a tendency to increase the amount of illumination provided in factories but to do so by using more powerful lamps in the installed fittings which were not designed for such sources. As the result of practical experiments and comparative studies in

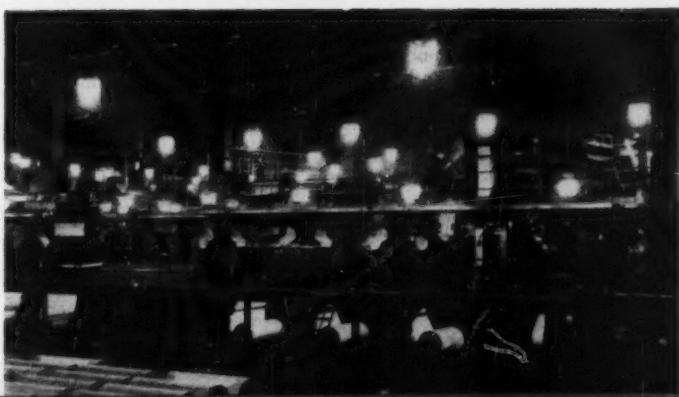
factories, more evidence as to what constitutes good lighting for industrial purposes was accumulated. In addition, experimental studies were made to ascertain how the efficiency of visual performance is affected by varying the illumination of work-objects of various sizes and degrees of inherent contrast. These basic studies—prompted by suggestions for a scientific lighting code made by A. W. Beuttell in 1932—yielded results which, 10 years' later, were utilised in the IES Lighting Code. In 1936, however, the IES published a list of "recommended values of illumination" for industrial and other purposes which was the precursor of subsequent codes.

A noteworthy industrial investigation of this period was that of S. Adams, which showed that, even in such visually unexacting work as tile-pressing, productivity did not closely approach its maximum until the illumination provided was more than double that of the mid-point value prevailing in the cotton industry at the time this story opens. Such a level of illumination seemed to be needed not so much for revealing the work as for giving the working environment a reasonably cheerful brightness. Both the Factory Lighting Committee and the Health of Munition Workers Committee had, earlier, commented on the depressing effect of many factory interiors, due to there being insufficient space lighting, and in the period 1928-1937 there were still many factories in which the artificial lighting was noticeably defective in this respect. Early in this period, however, the second post-war depression occurred and once again a check was applied to the improvement of factory lighting.

#### More Efficient Light Sources

At the same time, new and highly efficient light sources were introduced and both mercury- and sodium-discharge lamps were put to use in factories. Sodium lamps were claimed to be advantageous in foundries and mercury lamps were installed in machine shops and heavy engineering works, especially for high-bay lighting. They were also installed for lighting exterior areas of factory premises. These light sources gave rise to mixed feelings among the workers. The more adequate illumination which was often a consequence of their installation was welcomed, but their distortion of colours—particularly the colours of human beings—was not, and there were some complaints of stroboscopic effects.

It was not until the end of this decade that partially colour-corrected mercury lamps became available but, meanwhile, satisfactory "acclimatisation" to mercury lighting seemed to be achieved, and more agreeable colour-rendering was sometimes obtained by using both tungsten and mercury lamps in the same installation. The fittings most commonly used were vitreous-enamelled reflectors of the standard dispersive or concentrating types which gave no upward distribution of light. Industrial types of refractor were also in common use and a number of special-purpose fittings were utilised in appropriate situations. Enclosing fittings, sometimes combined with partly open-top steel reflectors, were also coming into use where managements appreciated that the working environment was enhanced by getting rid of



#### 1928-1936

From top to bottom : Three between-the-wars installations using tungsten lamps, in an engineering shop (1928), a battery-filling shop (1929), and a woodworking shop (1930). Bottom, mercury-vapour lamps in special prismatic units in a printing works (1936).



#### 1945-1958

**Top, an early fluorescent lighting installation.**  
**Above, good day-lighting in a post-war engineering works.**

the "tunnel effect," and there were even a few industrial interiors with indirect lighting.

The close of the decade was marked by an event that could not fail to give every factory occupier cause to consider the lighting of his premises. This was the enactment of the 1937 Factories Act. Under this Act, and for the first time, "sufficient and suitable" lighting, whether natural or artificial, was required to be provided in all factories, and the Chief Inspector of Factories was empowered to make statutory regulations defining definite standards of lighting. The Departmental Committee on Lighting in Factories was re-appointed by the Home Secretary to consider and advise upon the conditions to be prescribed by such regulations.

The fourth decade proved more momentous than its three predecessors. Although, in fact, no statutory regulations were brought into force until 1941, under the spur of the new Factories Act an upward trend in factory lighting began in 1938. Moreover, war-clouds were gathering once again and rearmament brought an increase in industrial activity, including overtime working, and the need to secure industrial efficiency by all means likely to prove effective. When the war materialised in 1939 its first effect upon factory lighting was an adverse one. The strict enforcement of the Lighting Restrictions Order compelled many factories with roof windows either to obscure them continuously—as the most effective and most quickly practicable way of preventing the egress of light

after nightfall—or to colour them blue and use sodium lamps for artificial lighting. Side windows were also restricted in effective area by temporary frames to accommodate shutters by night, or they were permanently "blacked-out."

In addition, artificial lighting installations which had been designed to provide reasonably good space lighting were modified by putting some points out of action, by changing fittings to obtain an exclusively downward distribution, or by substituting for the original lamps others of lesser light output. These changes were encouraged by a misguided appeal for economy in the consumption of electricity—misguided, for industry, because any lowering of the standards of lighting prevailing at the outbreak of war militated against the increase in productivity which was the urgent need of the time. Purely local lighting or, at best, localised general lighting became a fairly general practice—as it had been during the early part of the half-century we are considering. Yet, because there was necessarily a substantial increase in the number of hours during which work was dependent on artificial lighting, the situation called for an improvement rather than a worsening of conditions, while morale needed to be stimulated, not depressed.

#### A Sixfold Increase

By 1940, however, the emergency conditions of lighting in factories were causing no little concern. At the request of the Home Office, the Departmental Committee on Lighting in Factories reviewed the position and in June it made its fifth report, recommending that in factories generally a minimum illumination level of  $6 \text{ lm}/\text{ft}^2$ , at 3 ft. above floor level, should be attained, without prejudice to any additional illumination required by the nature of the work. Only two years previously the committee had not felt it necessary to go beyond recommending that, as a legal minimum, the illumination at floor level over interior working areas should not fall below  $1 \text{ lm}/\text{ft}^2$ . But the committee had become convinced that such a minimum would neither ensure that there would be sufficient light for ordinary work to be done efficiently nor that it would afford "reasonable amenity to the workers." As to the latter, it was recognised that the depressing and gloomy appearance of many factories was the result not of low illumination levels alone, but also of a failure to "decorate" the interiors in pale colours. So a recommendation was made to the effect that such interior parts of factories as bulk largely in the general field of view should be maintained light in colour.

At this time the writer was consulted by a special Inter-Departmental Committee as to what might be done to prevent any deterioration of morale in vital factories compelled to operate entirely by artificial lighting. The suggestion was offered that some attempt should be made to simulate natural lighting—not necessarily its colour, but its light distribution—by the location and size of light sources. It was fortunate that the 5-ft. 80-watt fluorescent tubular lamp was then available, though not "generally released," and so an experiment with artificial windows utilising these lamps was initiated in a blacked-out BTH foundry at Rugby. It was an unqualified success, the illusion of restored natural lighting being very satisfying. Although this method of artificial lighting was not repeated elsewhere, the advent of the fluorescent lamp, with its relatively large area, low brightness, high luminous efficiency and natural colour, meant that much could be done to "beat the black-out" even without artificial windows. The use of these lamps had to be restricted, but

in those parts of vital factories where their installation was authorised continuous artificial lighting in daytime was generally more acceptable than in its other forms.

Under the Ministry of Supply Act the Minister was given power to require good lighting in vital war factories under his control. In fact, such factories, together with those controlled by the Ministry of Aircraft Production and the Admiralty, were instructed to bring their lighting into line with the then current IES recommendations, which had been endorsed by the Factory Lighting Committee. The cost of the necessary re-lighting was met partly from grants made by the Ministries. To provide the essential advisory and planning service to expedite this large-scale re-lighting operation the electrical and gas sections of the lighting industry organised a national lighting service. New factories were built for war purposes and some of them were constructed without windows. All of them were lighted *ab initio* in accordance with up-to-date ideas of good practice. This meant that they were provided with general lighting to a level of illumination adequate for most of the work to be done, while local lighting was used only in situations difficult to light otherwise or where particularly high levels of illumination were required.

#### A Lighting Revolution

Thus, despite early mistakes, the war was responsible for what proved to be the beginning of an industrial lighting revolution. By the time hostilities ceased a large number of workers had become accustomed to conditions of artificial lighting distinctly better than they had previously experienced. They were heartily sick of the "black-out" but they knew that good artificial lighting was feasible and were not disposed to

revert to pre-war conditions. Of course, conditions of lighting for industrial operations which had to be carried on in outside areas of factory premises were seriously impaired during the war, and it is really astonishing that so much was achieved with so little light.

#### The Post-war IES Code

Six months after VE-day in 1945 a new IES Code was published. It incorporated, for the first time, the now familiar illumination charts and a method of assessing the illumination required for different visual tasks which was an outcome of the experimental studies made by the writer to which reference was made earlier. The timing of this new Code was opportune, for managements as well as workers had become less tolerant of poor or indifferent conditions and the former were ready to improve their factory lighting. Moreover, the status of the IES recommendations for industrial lighting practice was high and widely acknowledged. Restrictions on the supply of fluorescent lamps and associated equipment continued for some time, but, although grant-aided re-lighting schemes were no longer expedient for the prosecution of war, there began, on a considerable scale, a movement of reconstruction of factory lighting in premises where favourable changes had not been possible during hostilities.

The last decade, from 1948 to the present time, has been a period of continued reconstruction, as well as one of new construction, notwithstanding recurrent financial crises. In it, industrial lighting has, fortunately, received much attention. "Full employment" has meant competition for labour, and good working conditions—of which good lighting is one—have been found necessary to attract workers and to minimize labour turn-

#### 1950s

**Continuous rows of open-ended fluorescent trough fittings in weaving shed.**





### 1945-1958

Continuous rows of fluorescent fittings in (top) turbine house at Rye House power station, Hoddesdon, Herts, and (centre) Ferguson television factory, Enfield, Middlesex. Bottom, luminous ceiling, supplemented by spotlights, in control room of Earley generating station.

over. Early in the decade the process of removing war-time obstructions to the admission of daylight had not been completed in some factories and delivery of new window glass was slow. But the range of tubular fluorescent lamps was being widened and those available included 20- and 40-watt as well as 80-watt lamps, and "warm-white" as well as "daylight" colour.

Fluorescent lighting spread rapidly in factories as an ample supply of lamps and gear became available. Frequently the lamps were installed in continuous rows and a veritable transformation was effected in the appearance of many factories and in the conditions prevailing for seeing to work. Inevitably there were some complaints from workers—as there have been on every previous introduction of a new light source; history was merely repeating itself. Some of these complaints were justified because, in their haste to obtain the advantages of the new lamps, users did not always have them installed suitably.

Cold-cathode fluorescent lighting also was applied in some factories and, as an adjunct to improved lighting, many factory interiors were brightened by repainting.

Year by year since the war HM Inspectors of Factories, who have unrivalled opportunities for noting industrial lighting, have been able to report steady progress toward a generally satisfactory state of affairs, though it would be a mistake to suppose that lighting in many factories does not still leave much to be desired. In general, there is now good lighting in factories designed and built during the past few years. These years have been marked by the introduction of new installation techniques, such as the use of continuous trunking and of "in-built" luminaire receptacles. Also, many new diffusers, reflectors and refractors have become available, together with new and more efficient light sources and other devices, such as luminous ceilings.

Looking back over the past 50 years, we see, at the outset, a state of industrial lighting that caused concern for the welfare of factory workers and pointed to the need for protective legislation. We see improvements slowly come about: partly because of the attention drawn to the subject by government committees and by the Press, including this journal; partly because of the increased interest in productivity touched off by an unparalleled war; and partly because of the accumulation of scientific evidence as to the favourable effects of better lighting. But, in truth, perhaps the main factor that has led to such improvements as occurred during the first 30 years was the development of more efficient light sources and a fall in the cost of energy for operating them. Later came the spur of statutory lighting regulations and the urgent need for high productivity brought about by the 1939-45 war. This war, while retarding lighting progress in many factories, accelerated it in others where the cost of improving installations was partly met by the State. Finally, in the post-war years, unprecedented progress has been made, because of the much wider recognition of the advantages of good factory lighting and knowledge of what constitutes good lighting; because of industrial prosperity and the need to attract and keep labour; and, not least, because of the efforts of the lighting industry itself.



By P. Petherbridge, M.Sc.\*

## 7

# Daylighting Trends

THE existence in England of ancient laws of light, established during the Roman occupation and surviving to the present day, has meant that architects and others in this country have for long been "daylight conscious." This continual awareness of the need for adequate daylighting has not only influenced building design but, particularly during the past 50 years, has fostered the development of techniques for calculating and measuring daylighting levels.

What then was the kind of thought being given by the building designers of 1908 to daylighting problems? With such distractions as the Franco-British Exhibition and the Olympic Games held in Britain at that time, was any attention being given to the ways in which interior daylighting could be improved? The architectural publications of 1908 indicate that great concern was being shown for the succession of fires then causing serious damage to property in Britain and abroad, but these publications also give evidence that architects and others were ready to absorb new daylighting techniques and to appraise the solutions which their colleagues had to offer for the daylighting of new buildings.

### 1908-1958

**Fig. 1, daylight factor measuring instruments. (By courtesy of Holophane, Ltd. and the Building Research Station.)**

A guide to the daylighting conditions commonly met with in buildings 50 years ago is given by the typical levels of interior daylighting which P. J. Waldram published in this journal's forerunner, *The Illuminating Engineer*, in 1909. For new urban technical schools and ordinary offices, these levels correspond to daylight factors of between 0.25 and 0.33 per cent. The great improvements in daylighting conditions which have come about since can be judged by the fact that the corresponding daylight factors recommended to-day lie between 2 and 4 per cent. The low levels which Waldram measured make it understandable that a glass substitute material could be advertised in 1908 which comprised a web of fine iron wire covered on both sides with a thick varnish of various shades of amber and green.

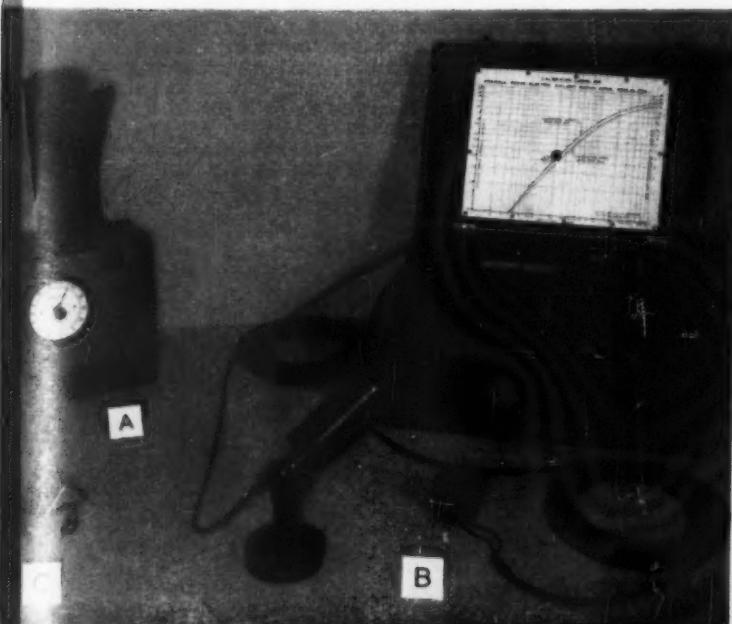
### Daylighting "Coefficients"

Reference has been made to early measurements of interior daylighting. Although the term "daylight factor" was not introduced until 1928, the basic idea of expressing the indoor illumination as a ratio of the prevailing outdoor illumination was conceived by Trotter as long ago as 1895. By the time this journal first appeared Waldram was already measuring Trotter's daylighting "coefficients" for various buildings, and it is from some of these coefficients that the daylight factors quoted earlier were derived.

In those pioneer days the photo-electric cell was only at an early stage of development. The illumination measurements necessary to determine the daylighting coefficients had to be made, therefore, with the relatively elementary visual photometers then available. Nevertheless, this situation did not deter Waldram from advising in 1910 that measurements of both artificial and natural illumination were such a very simple matter, requiring neither special skill nor expensive apparatus, that they should be undertaken largely by architects.

This statement should be borne in mind when studying the daylight factor measuring devices shown in Fig. 1, for it would appear that the subsequent introduction of the photo-electric cell complicated, at least initially, the problem of natural illumination measurement. In this photograph the relative compactness and portability of the original Trotter visual photometer and Waldram daylight factor attachment (A) is compared with the corresponding bulk of the NPL photo-electric daylight factor meter (B) designed 30 years later for use by the specialist. Almost another 15 years were to elapse before the development of the extremely compact and portable EEL/BRS photo-electric daylight factor meter (C),

\* Of the Building Research Station.



again intended for the person who neither possesses special skill nor can afford expensive apparatus.

The architectural pattern of most large public and private offices of 1908 is typified by some of the buildings which were erected in Whitehall at about that time and to-day largely determine the character of that thoroughfare (Fig. 2). The size and number of the windows in these buildings arose from considerations of elevational proportions rather than from daylighting requirements. The depths of the walls and the overshadowing caused by external decorative features resulted in lower daylighting levels than would be achieved in a similar type of building to-day.

An office building of about this period which departed widely from contemporary design practice is Sir John Burnet's Kodak building, erected in Kingsway, London, in 1911 (Fig. 3). The problem of satisfactory daylighting was resolved by making a building of windows rather than of walls. The functional nature of the building was emphasised by omitting the "rubbish of pastiche, senseless mouldings and extravagant ornamentation" from the exterior of the building, and this omission contributed toward improving the daylighting conditions. The architectural Press of the time credited Sir John with not only having evolved the ideal type of office building, but with the far greater achievement of having inaugurated a new movement in architectural design.

In 1908, men such as Walter Gropius, whose work and teaching were to have by far the greatest impact on daylighting design during this journal's existence, were just finishing their training. Functional design and the use of machine-made components were yet to come.

Achievements in building construction during the period should be reviewed against available materials and developing technology. For instance, it was not until 1913 that sheet glass was first drawn flat on a commercial scale, obviating the double process of blowing and flattening. Plate glass, which was used extensively in R. Frank Atkinson's Selfridge store in Oxford Street, London, in 1908, was polished by a long and tedious process which was only superseded by techniques introduced after the first world war. Although framed construction was being used before 1908, it was not until later that its potentialities were fully explored. The result has been to give the outer skin of a building a freedom which has made possible thinner walls and larger windows, reaching in its ultimate limit the glass curtain wall.

#### 1911-1929

**Left to right :**  
Fig. 2, Government Offices in Whitehall (1908);  
Fig. 3, the Kodak building, Kingsway (1911); Fig. 4,  
No. 55, Broadway (1929).



A point quite often overlooked, even to-day, but fully appreciated in those early days, is that a building interior receiving a given proportion of the illumination outdoors will be adequately lit only if the outdoor value is sufficiently high. This point has stimulated the study of the variation of outdoor illumination with the time of the day and the season of the year in various countries.

Some of the earliest of these daylighting measurements, made in Chicago, were reported in the first volume of this journal. By the time the memorable 1915 Factory Lighting Report was published, a number of daylighting curves had become available for this country. The measurements made continuously at the NPL between 1923 and 1939 are some of the most well-known measurements in this branch of daylight photometry. It is from an analysis of them made during the earlier part of this period that the level of 500 lm/ft<sup>2</sup> was derived as representing average dull-sky conditions in Great Britain.

To-day, continuous recordings of daylight illumination are being made in this country at such places as Kew Observatory and the CEA Research Laboratories, Leatherhead. At Kew, the measurements of M. J. Blackwell have been combined with simultaneous recordings of total solar radiation to derive a measure of the luminous efficiency of daylight. The value of approximately 125 lm/W thus obtained provides a challenge to those dealing with the development of more efficient artificial illuminants.

A summary of daylight photometry during the last 50 years would be incomplete without mentioning the measurements made by H. H. Kimball and his colleagues at the U.S. Weather Bureau in the early 1920s of the distribution of sky luminance, which are still a standard source of reference. In 1942, Moon and Spencer expressed Kimball's measurements for the densely overcast sky by a simple empirical formula, and it is this formula which was adopted internationally for daylighting design purposes at the 1955 CIE meeting.

#### Rights of Light

The jealous guardianship of rights of light in Britain has resulted in the evolution of a highly specialised branch of litigation in British courts of law. Before the development of scientific methods for measuring and predetermining interior daylighting levels, however, it was common for professional witnesses to flatly contradict each other in open court on matters of opinion and observation relating to rights-of-light cases. On the other hand, by the early 1920s, legal disputes

over obstructions to light were frequently being decided by mutually agreed measurements or settled out of court, and this development was brought about in no small measure by the important contributions to the subject made by that "expert witness," P. J. Waldrum.

In 1923, P. J. Waldrum, in collaboration with his son, J. M. Waldrum, published in *The Illuminating Engineer* their diagram for daylight calculations which subsequently became so widely known. This diagram, and the calculating diagrams introduced by J. Swarbrick in 1929, ultimately became generally accepted in courts of law for daylight litigation purposes.

#### Daylight and Town Planning

The long-standing concern in Britain for an individual's enjoyment of adequate daylight has had an impact on the framing of building bye-laws and other similar regulations, thus ensuring that buildings in densely developed areas receive some view of the sky. The controls have taken various forms, including limitations on the degree of coverage of a site and on the height and spacing of buildings. Where these limitations have been imposed in terms of a maximum angle of setback from the opposite building line, they have usually produced the characterless vista of whole rows of buildings either of a uniform height or with their upper floors retreating in steps from the building line.

Development to the limit of a building line has often resulted in buildings (particularly office blocks) of such depth that the provision of one or more light wells has been essential, though in practice these wells have rarely contributed satisfactorily to the daylighting of the rooms facing on to them. In 1928, J. G. West demonstrated that a building which was H-shaped in plan would receive direct-sky light over more of its floor area than would buildings of more conventional shapes occupying the same site area. This idea of, in effect, putting the light wells on the outside of a building was successfully realised (probably for the first time in Britain) in 1929, when the offices now occupied by the London Transport Executive were erected at 55, Broadway (Fig. 4).

The advantages of the cruciform type of plan for the daylighting of large buildings was subsequently to become more widely appreciated as the result of studies carried out by W. A. Allen at BRS and by D. H. Crompton, under the direction of Professor Sir William Holford, at the former Ministry of Town and Country Planning. These studies were concerned not only with buildings of different plan shape but also with the positioning of individual buildings relative to their neighbours. They led to the production of a method for controlling building development which was more flexible than the uniform angular restriction previously imposed, resulting in an alternative deeply serrated outline to the obstructing buildings with, in some cases, development to an unrestricted height over part of the site.

This aid to town planning, sometimes known as the Daylighting Code, was adopted by both the County and City of London in executing their post-war reconstruction schemes. An example of the type of building resulting from this kind of planning control is Fountain House (Fig. 5), a new block of offices in Fenchurch Street, London. This building has two storeys over the entire site and two towers, one of them 14 storeys high, over part of the site. Such a building could never have been passed by the planning authorities on the basis of the old uniform angular limitation.

The outbreak of the second world war brought with it problems of blackout, particularly of industrial buildings. It was necessary, moreover,

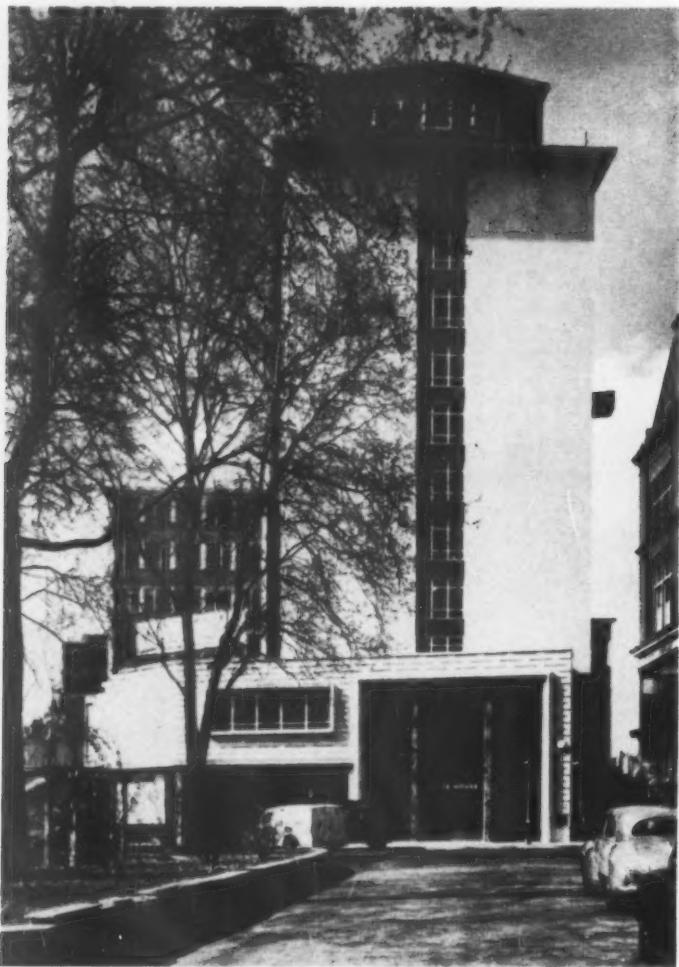


to leave unprotected from blast and shrapnel only the barest minimum of roof glazing. In the design of war-time factories this barest minimum was often all that was provided, and a series of sky-factor protractors was introduced by BRS in 1940 to facilitate the estimating of the required size and position of the glazing. Although originally conceived for a war-time purpose, these protractors have subsequently become an established method of calculating interior daylighting in Great Britain.

Inevitably, windowless factories were considered, at least as a war-time measure, since the dual

**1957**

**Fig. 5, Fountain House, Fenchurch Street—the type of tall building made possible by the Daylighting Code.**



**1957**

**Caltex House,  
Knightsbridge.  
Tall building over  
part of the site,  
avoiding "setbacks."**

problems of blackout and adequate roof protection could then be resolved simply. Nevertheless, the workers' reactions to a completely artificially lit environment were not forgotten, and the recommendations made at that time for windowless factories were concerned not only with providing higher levels of illumination than in the average pre-war factory, but with ensuring that these levels would be accompanied by adequate diffusion of the light from the surroundings, as is usual in daylit interiors.

The Departmental Committee on Factory Lighting observed that the admission of even a fraction of normal daylight made an enormous difference to the amenity of a workshop. Heeding this, and bearing in mind the advantages of a completely windowless factory, various managements endeavoured to allay unfavourable reactions from their workers by installing artificial sky-lights. In fact, by 1940 this idea had already been tried out in a number of factories, where the north-lights were permanently blacked-out and artificial sky-lights lit by the recently introduced fluorescent lamp were installed below them.

No sooner did the war enter its final phases than attention was given increasingly to the lighting problems which would arise in post-war reconstruction. The IES published a series of Lighting Reconstruction Pamphlets, of which No. 4, issued in 1944, dealt with natural daylighting. Another

important contribution was Post-War Building Study No. 12, in which the science and practice of the daylighting of buildings up to the date of the publication were given in great detail. This study was followed in 1952 by a similar document concerned specifically with the lighting of office buildings.

#### Post-war Daylighting Research

Post-war developments in daylighting have been marked by extensive laboratory studies in Britain and abroad, aimed ultimately at producing simple but accurate methods for calculating interior daylighting, including the light reflected from the room surfaces. Initially these studies were directed toward measuring the required levels in models for numerous room conditions and, in this connection, the work of Pleijel at the Royal Institute of Technology at Stockholm has been of particular importance. More recently, model rooms and artificial skies have been used extensively, both in Britain and abroad, to study the daylighting of specific rooms and to check on the accuracy of methods of calculating the amount of reflected light in a room. It is of interest that the first volume of this journal included an article by Professor Ruzicka, of the Bohemian University at Prague, describing what was probably one of the first applications of a model room and artificial sky to a daylighting study.

The emphasis in this article so far has been on the quantity of daylight, rather than its quality. Quality factors have, in fact, made themselves increasingly felt in interior lighting in recent years, and their impact on daylighting can be judged by comparing the four pages of the 1949 edition of the IES Code devoted to natural lighting, with the 12 pages devoted to the subject in the 1955 edition. Nowadays the design and position of windows and the decoration and orientation of surfaces in their immediate vicinity are given as much attention as the levels of daylighting they produce. In this respect, the work done by the Development Group of the Ministry of Education under S. A. W. Johnson Marshall and A. Pott, and by the Division for Architectural Studies of the Nuffield Foundation under R. Llewelyn Davies, jointly with the BRS team, has enabled laboratory studies of the quantity and quality of daylighting in schools and hospitals to be carried through to the final buildings.

#### Outlook for the Future

What form is daylighting progress going to take during the years before the centenary of this journal is celebrated? In the U.S.A. there is already a strong feeling that the only useful function of a window is to provide a view outdoors, and that light for seeing indoors is best provided artificially. Does this idea spell the doom of the window and all the vast technology of daylighting? Has someone only to replace the view window with a television screen, as was suggested at an American window conference in 1956, for our Waldrum diagrams and inter-reflection formulae to be condemned to the scrap heap?

Inevitably comfort in daylit interiors will be given more attention in future years. The control of visible-sky luminance within acceptable limits by neutral-tinted glass is a method which was advocated by R. G. Hopkinson in 1950 from the results of BRS discomfort-glare work. It has since been tried out in the U.S.A. with some success. In another 50 years it is conceivable that windows of an infinitely variable density, like giant polarising filters, will be developed to cope with the enormous variations in sky luminance, yet to allow an undistorted view outdoors.

By J. M. Waldram, B.Sc., F.I.E.S.\*

## 8

# Fifty Years of Street Lighting

*"MOUNTING height, 28 ft.; spacing, 127 ft.; arrangement, staggered; width to building face, 50 ft.; watts, 500; luminous efficiency, 62 lm/W."*

*"The minimum value of the illumination should not be less than 0.1 lm/ft<sup>2</sup>."*

*"The lantern emits 19,000 lumens in the lower hemisphere."*

These figures might well apply to good modern street lighting, except that the reference to minimum illumination is out of date. In fact, they are taken from Volume I of "The Illuminating Engineer" in 1908, with the values expressed in current units. It seems to be true that "We can do the old tricks better, more accurately and as a commercial proposition, but they are old tricks. The optical laws involved are few and well known, and we have exploited them years ago."

This first volume makes sobering reading. We anticipated ourselves far more often than we like to think. Street lighting began seriously as soon as there were sources to make it possible, and 50 years ago there was a good deal of it. Cities planning their street lighting sent delegations abroad and reported on developments; for example, in 1908 a delegation from the City of London visited a number of European cities, and American delegations came over. There was a cry for measurement, and Trotter and Haydn Harrison were busy with instruments. Detailed specifications were drawn up carefully, and trial installations and tests were made. There was a bitter war, in Britain at least, between gas and electricity, with unsupported warnings that the other illuminant was bad for the eyes, exactly paralleled by recent fears about fluorescent lamps. "Is there anything whereof it may be said, 'See, this is new?' It hath been already of old time, which was before us."

In 1908 the filament lamp was just appearing in a lighting world dominated by gas and arc lamps. The arguments of those days were about the relative merits of upright and inverted mantles, high pressure and low, and gas *versus* various electric arcs. Lighting engineers had found by experiment the geometrical parameters of a successful installation, which were much as we know them to-day, but they had not progressed much with light distribution. There were gas lamps of various kinds, usually with clear globes, and many high-pressure gas lamps were installed in London in 1910. In some places there were naphtha lamps and flat-flame gas burners, which were still used in 1916. There were plain carbon arcs, enclosed arcs, flame arcs, magazine arcs, magnetite arcs and titanium arcs.

Light distribution was governed largely by the shape of the mantle or the arrangement of the electrodes, and often by the type of diffusing globe used. Serious attempts to produce an appropriate distribution came a little later. It is curious that the flame arc was little used in America, where the magnetite arc, found nowhere else, was used in tens of thousands. Similarly, in the USA there were developed elaborate constant-current-distribution systems for public lighting, widely used to-day, but found scarcely at all elsewhere.

The efficiency of the gas lanterns was presumably little less than that of more modern lamps; that of the arcs was remarkably high compared with tungsten filament lamps. The magnetite arc, so widely used in America, is quoted as 0.35 W/cd, or 36 lm/W; that of the flame arc is quoted as 0.2 W/cd, or 63 lm/W. These figures are for the lamp, without ballast losses, but the lamps were usually run in series (in the USA on constant current) so that ballasts were not necessary. However, these efficiency figures need interpretation. The writer thoroughly tested in 1926 a German flame arc-lamp designed for street lighting. The luminous efficiency of the complete lantern was found to be 0.56 W/cd, or 22.5 lm/W, with the lantern clean, but fell to 14.6 lm/W, without ballast losses, when the lamp was dirty. It had to be re-carboned and cleaned every 8 to 14 days, according to the time of year, and during that period it accumulated a large beaker-ful of white ash. It had works like a clock, beautifully made and would cost to-day £50 or more. A flame arc was quoted as costing, in 1909, about £27 a year to run. One wonders what the maintenance costs would be at to-day's labour charges. We have certainly made some practical progress since then.

### Experiments and Specifications

In those days lighting was empirical, but in the USA in 1910 A. J. Sweet made a theoretical study, with physiological experiments on glare, working out the light distribution required for uniform illumination, indicating the glare effects and the ways in which they could be avoided, and the desirable minimum illumination and maximum spacing-height ratio. This study set the course of American thought for many years to come.

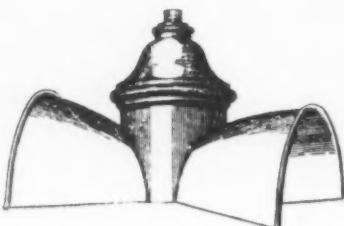
In 1913, Trotter was chairman of a committee which attempted to draw up a specification for street lighting. By 1914, refractors had appeared in the streets, giving peaky light distributions not very different from Sweet's theoretical distribution. In America they were used with magnetic arcs, in Britain with tungsten filament lamps which were beginning to replace arcs in both Europe and America. Preston Millar in the U.S.A. made

\* Of the Research Laboratories, the General Electric Co. Ltd., Wembley, England.



#### 1909-1926

Above, street-lighting standards illustrated in Vol. II of *The Illuminating Engineer*. Left to right: Thames Embankment; near Town Hall, Battersea; suggested model based on "Duke's Head" sign at Leatherhead; standard used near Queen Victoria Memorial, London. Centre, the "Equilux" reflector designed by C. H. Sharp in the U.S.A. in 1910. Bottom, street-lighting arc lamp, 1926.



in 1916 some characteristically thorough and imaginative experiments on visibility, pointing the way to road-surface effects and road lighting which bore fruit later. A committee was formed in America but held up by the First World War. In Britain there was "blackout": nothing like the blackout—the smaller parts of square gas lanterns were painted with black paint, and the larger lamps, such as arcs, were extinguished.

Soon after the war, street lighting began to develop. The gas-filled tungsten filament lamp, which had appeared in 1913, had ousted the arc, and competition with gas lamps, which were firmly entrenched, was bitter. In America, gas and electric corporations were formed, which was a simpler way round the difficulty. More formal study of street lighting began, and the British Engineering Standards Association set up a committee with C. C. Paterson as its chairman to prepare a specification. Before that time, the local surveyor or the council would prepare a specification of its own, usually by the light of nature. The writer recalls one of his first tasks connected with street lighting, which was to go into the Strand with a Holophane Lumeter and a piece of string, which had two knots in it at distances measured from the column corresponding to 55 and 75 deg. from the vertical. It was necessary to take periodical observations of illumination at these points to check compliance with the specification.

At this time, though most of the lighting in Britain was by gas, new lighting installations used gas and electricity about equally, and many experiments were made with new methods of control of light flux from both illuminants, the aim being the more uniform illumination of the road surface, though results were inexplicably variable. Theoretical studies of glare by Bordoni in Italy, Holliday in the U.S.A., and Stiles in Britain were applied to the problem, and Walsh worked out a method of calculating glare from the parameters of an installation which appeared in the first British Standard Specification of 1927. It is interesting to note that in this calculation, in the absence of better data, it was assumed that the road surface was matt and of 10 per cent. reflection factor. This resulted in very low assumed luminance of the road surface and consequently the effects of disability glare were grossly overestimated—a mistake which bedevilled street lighting for many years, and for which the present writer was partly responsible.

#### Colquhoun's Experiment

The BESA Committee sought a method of rating street lighting according to the calibre of the installation, and decided to use as a basis the minimum illumination in the street. The corresponding American committee, and the French lighting engineers, were following interior lighting practice in thinking of the average. Soon after the first British Standard Specification had been published there were two events of some importance. The first was the great experiment made in 1928 by Colquhoun at Sheffield, in connection with his presidential address to the Association of Public Lighting Engineers. He erected or arranged in Sheffield no less than 50 installations of all kinds large and small, orthodox and unorthodox, measured their characteristics; made the measurements available to delegates and arranged visits and studies. The NPL took the opportunity to make some detailed observations. It was an experiment which for completeness and scale has never been surpassed, and it provided a unique opportunity for study. Some of the installations raised queries which led later to important developments.



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Photograph by courtesy of G. Cowan, Esq., A.M.Inst.C.E., M.I.Mech.E., A.R.I.C.S., Engineer and Surveyor, Stockton-on-Tees.

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Shortly after this experiment, there was the 1928 meeting of the CIE in the United States, and a strong British delegation discussed with vigour the conceptions which had formed themselves in the minds of the BESA Committee, reinforced with the data of the Sheffield experiment. The contestants agreed to differ, and it was recommended to adopt internationally as essential characteristics both the minimum and the average illumination, and also to collect information about interesting installations in all countries. In the next revision of the Specification, there appeared a method of ascertaining the average illumination. The glare calculation was dropped, having been found to be insufficiently exact.

Insistence on the minimum illumination had, however, two unfortunate consequences: firstly, notwithstanding the Committee's homilies, the minimum illumination was regarded not merely as a rating, but as a figure of merit, which clouded the issue; and, secondly, lanterns were devised and adjusted to spotlight the "test point," which destroyed the basic assumptions on which it had been adopted. It soon became obvious that this parameter had lost its usefulness.

#### The Introduction of Discharge Lamps

At this moment, a new direction was given to our studies by two other events: the coming of discharge lamps—sodium on the Continent and HPMV in England—and the activities of the Ministry of Transport. The discharge lamps gave a tremendous impetus to development and research. To designers who had known no light source but the tungsten filament lamp they were a stimulating challenge, and quite new lanterns were produced, having perforce unconventional distributions, for the first HPMV lamps would only burn vertically. It became clearer than ever that the basis of the Specification was inadequate. Theoretical studies were intensified. The properties of the road surface were studied in Britain, France and the Netherlands, and in Britain a new approach to the problem was worked out. This approach was, in fact, the first practical example of "brightness engineering." Illumination was abandoned; the installation was considered in perspective; and the mechanism of street lighting began to be understood. It was recognised that luminance was too variable ever

to be used for rating or specification, but the geometrical and distribution parameters were devised so that if they were complied with a satisfactory level and distribution of luminance would result, provided the road surface was reasonable.

Much of the research which led to this conclusion was made by a Departmental Committee set up by the Ministry of Transport. In 1937 the committee produced its well-known report, which has dominated British street-lighting practice ever since, and has had much influence abroad. It incorporated a revolutionary approach, based on two fundamental and realistic principles, which have been adopted by no other country in their entirety. The first is that it is desirable to attract traffic to traffic routes as much as possible, and to keep it out of residential roads: the committee recognised, therefore, only two corresponding and clearly distinguished classes of installation. The second is that lighting designed for traffic should be really safe for driving without headlights; and furthermore that just as much light is required for one vehicle as for twenty, on the principle that it takes no more noise to wake seven sleepers than to wake one. The committee avoided, therefore, any correlation of street lighting with the amount of traffic, as has been done in most other countries. Some modification may be necessary for streets which are so choked that one can see nothing but other vehicles, but this point has not been established. The MOT Report, made much later the basis of a BSI Code, has provided an excellent basis and has led practice for 20 years. It is a tribute to the committee's farsighted approach that only now has practice caught up with it, and it is beginning to drag rather than to lead. The time has come for a revision and extension, but not for any radical change of policy.

#### The Second World War

Before the BSI could produce the findings of the MOT committee in the form of a Code, the second world war came, and a sinister and strict specification was imposed, the fruit of urgent experiment. Street lighting equipment was made in the form of small black tin pressings, emitting a minute flux of light rigidly distributed. On all but very dark nights the lighting could not be discerned on the ground, yet it could be seen from

#### 1919-1939

**Street-lighting standards in use between the wars.**  
Left to right: late 1920s; first public installation using discharge lamps (1933); concrete standards (mid-1930s).





### 1930s

**Top, a historic test installation—the MOT experiment at Lonsdale Road, Barnes, in 1935. Above, in the City of Salisbury, on the A30 route (1937).**

the air from surprisingly great heights. When peace came the enthusiastic teams of pre-war experimenters had dispersed, and the tempo was much slower.

With the coming of discharge lamps had come developments of characteristic street lighting systems—the non-cut-off system in Britain and the cut-off system initially on the Continent. Various factors and accidents led to these developments and the two systems have since tended to approach one another. Present-day systems, with their more generous spacing, tend to be of an intermediate type.

New developments have centred mainly upon the new types of lamp, and in recent years the situation of 1910 has repeated itself. We now have several sources available, some favoured in one country

and some in another, each of which has caused the development of its own type of lighting equipment. Sodium lamps, HPMV lamps and tubular fluorescent lamps have been developed to very high efficiencies and long lives.

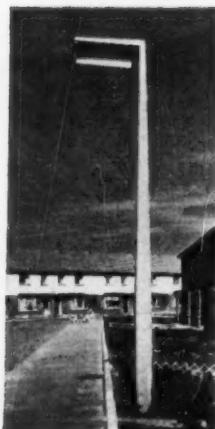
The HPMV lamp is now available with a fluorescent coating—a promising form which has been adopted widely on the Continent and in America, but which has been taken up curiously slowly in Britain, hitherto a country that has led in the adoption of new lamps. The tubular fluorescent lamp so widely used indoors is an unpromising lamp for public lighting, and it was at first thought absurd to use a lamp of such large size and small output, several of which would be necessary in every lantern. However, initial and rather half-hearted experiments were surprisingly welcomed, and the tubular fluorescent lamp, in enormous lanterns in which efficiency can seldom be accompanied by elegance, has been widely used in many countries. The cold-cathode lamp has been used tentatively, on the grounds of its very long life; but if this is to be exploited fully some revolutionary lantern designs are called for. Gas, which has had a long and gallant run for 100 years and more, is finally abandoning the unequal contest, and no new gas installations are appearing in England. Tungsten lamps are showing themselves to be very expensive compared with the discharge lamps, and are little used in Britain for new traffic-route schemes, though they are still widely used in America. For Group B lighting they are usual, for there is less advantage for the discharge lamp in these sizes, and malicious breakages of discharge lamps become very expensive. We now have available tungsten filament lamps, sodium lamps, HPMV, MBF (mercury fluorescent), MCFU (tubular fluorescent, hot cathode) and cold-cathode lamps, each with advantages and defects, each demanding its own lighting equipment, and each popular in some country, though none equally in all countries. Street lighting seems to be a fashion trade.

### Street-lighting Equipment

Lighting equipment has undergone considerable development, much of it during the last 10 years. In Britain the early gas lanterns were made by tinsmiths, and the early electric lanterns were copied from them, just as the early cars were copied from the horse carriage. The construction was weak and inaccurate. Before the war die-casting was in use for lanterns and, with the great advances since the war in die-casting and extrusion, the use of aluminium alloys (in the production of anodised aluminium reflectors) and the use of plastics (either shaped, machined, extruded or injection-moulded), lantern design has undergone a complete revolution. Modern lanterns are accurately made, durable and weatherproof. Used with discharge lamps of long life and with synchronous astronomical time switches (or more elaborate methods of control), they require little more than wiping outside and need be opened only about once a year.

The design of columns has been for some time in the direction of simplicity and slenderness. The early columns were sometimes horrid examples of unnecessary ornament, though they were very carefully designed aesthetically. Cast iron has been replaced by steel, which is much safer; and concrete columns, first used in the '20s, have been made slimmer and more graceful, especially with the development of prestressed concrete.

Over the whole period lighting engineers have been concerned with the aesthetics of public lighting; the following extract might have been written



### 1945-1958

Left, post-war lighting standards for fluorescent lamps. Below, post-war installations (from top to bottom): Waterloo Bridge, London, completion of scheme by addition of centre columns (mercury vapour, 1953); vertical-mounted fluorescent lanterns at Rayleigh, Essex; wall-mounted lanterns housing cold-cathode tubing (Union Street, Aberdeen, 1955).

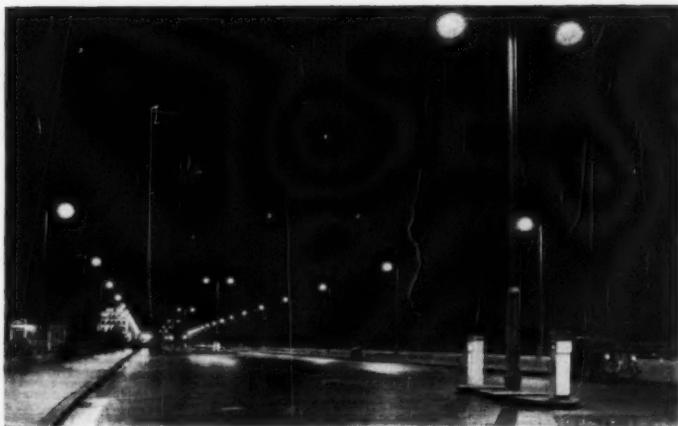
yesterday: "... I ought to point out the unsatisfactory condition of London in the matter of lamp standards, and especially electric lamp standards. The design is usually left to an ironfounder's draughtsman. Mr. Norman Shaw has very kindly given his gratuitous aid in matters affecting the appearance of London, and I think his help might very well be asked...." The quotation is, in fact, taken from the report of the Electrical Engineer to the Streets Committee of the Corporation of London in 1908 (*Illuminating Engineer*, 1, 568).

#### Variety of Installations

To-day the advice is still gratuitous, still negative, and more barbed. If anything, some of it seems to favour the designs of 1908. Fortunately, the Council of Industrial Design provides the mere engineer with a partial shelter from the blast.

To-day we are seeing here and abroad, in addition to thousands of miles of street lighting designed to the various national Codes, experiments which go beyond them. There are installations with vertical fluorescent lamps, in which efficiency has been frankly abandoned in favour of appearance; installations with fluorescent lamps on the façade parallel to the street axis; others with the lamps similarly oriented but on central columns or very light span-wires—all at extremely short spacing; large lanterns with MBF lamps, mostly abroad; cut-off lanterns with their axis inclined towards the centre of the road, long popular in France and the Netherlands; slim one-lamp fluorescent lanterns made to grow from a slender curved column, like a bud on a daffodil stem, higher than usual and at very short spacing; experimental installations with very high power; and bridges lit by continuous lamps in the parapet.

The Codes are bursting at the seams. Theoretical work has been concentrated on the relationship between street lighting and accidents, and on visibility; a Working Committee of the CIE is charged with the investigation of these and related problems. Attention is being turned to the lighting of residential streets, into which some elaborate investigations have been made. Perhaps the direct relation between street lighting and accidents is too tenuous to provide information in the necessary detail, and the most recent work is along another approach. The aim of street lighting is to provide the road user with all the information he needs, with the proper emphasis, and with equipment as cheap and as beautiful as possible. We are not yet sure how near we are to these goals, but it may be that we shall soon find out.





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# 9 Floodlighting : Decorative and Functional

By W. E. Rawson Bottom, Assoc. I.E.E., F.I.E.S.\*

**F**LOODLIGHTING as it is known to-day began its popularity with the advent of the gas-filled lamp. Little was known of this form of lighting before the first world war, though searchlights using electric arcs were used for lighting waterfalls, military displays and the like during the latter part of the nineteenth century.

Outlining buildings with light is not floodlighting in the accepted sense of the word but can be regarded as part of its ancestry. It goes back many years before the introduction of floodlighting—the light sources ranging from floating wicks in coloured-glass oil containers to lines of "fish-tail" gas jets and, later, five-candle-power carbon "loop" lamps. Some scintillating effects were produced by gas jets inside decorative motifs constructed of cut-glass beads.

Perhaps the first large scheme in Great Britain using carbon filament lamps to outline buildings was carried out at the Franco-British Exhibition, at Shepherd's Bush in 1910, and many buildings in London were treated in this way for the coronation of King George V in 1911. Even to-day this method of festive lighting is still popular where brilliance and gaiety is the keynote.

It was during the latter part of the 1914-1918 war that the external lighting of buildings began when it was first used at the great Panama Pacific Exhibition in the United States and was then referred to by the Press as "floodlighting." The

lighting of the famous 58-storey Woolworth building was an outstanding example at that time and demonstrated the possibilities of revealing at night the architectural features of a building—even one of so great a height. Some 600 long-range projectors were located on adjacent buildings and this method was used extensively for lighting skyscraper buildings throughout the United States.

Because of the war little was possible in Britain until the British Empire Exhibition took place at Wembley in 1924. Before this event, however, much was done by manufacturers in the way of designing efficient outdoor lighting equipment to be used for a variety of purposes.

A number of the exhibition buildings at Wembley had plain façades and presented few difficulties, but some were designed to represent the architecture typical of a particular country. For instance, the Indian pavilion, besides having its minarets and colonnades, had a replica of the famous Taj Mahal constructed in white plaster. The lighting of the minarets and dome was by specially designed reflectors, using lamps of up to 1,500 watts which projected an elliptical beam. One of these units lit a tower about 90 ft. in height. The positioning of the reflectors was carefully considered to produce the appropriate light and shade, to give shape and perspective, and to reveal the beauty of the delicate tracery. The façade was lit by parabolic-mirror trough reflectors placed close to the building. Specially made 200-watt line filament projector lamps were used and may well have been the forerunner of the present "Horizon" projector lamps. Incidentally, the scheme was in two colours, changing imperceptibly from sunlight to an oriental moonlight effect.

The Burma pavilion, with its graceful spires constructed in beautifully carved teak, needed different treatment and the building had an awe-inspiring effect when seen against the night sky. The Wembley Stadium buildings were also illuminated and the lighting of the arena for the rodeo and tattoo spectacles probably suggested the idea of providing light for football and other sports at night.

## Commercial Buildings

From about this time onwards the floodlighting of buildings became popular and one of the earliest examples was the Selfridge building in Oxford Street proving, as it did, the publicity value of a well-lit building. This example was followed soon after by a number of well-known buildings, including hotels, theatres, commercial buildings and churches.

All this additional light in our cities, including the lighting of poster hoardings, began to add to their colour and gaiety and helped in no

\* Of the Ministry of Works.

1926

First example  
of floodlighting  
of a commercial  
building.  
Selfridges,  
Oxford St.





## **When we were 12 years old -**

—“Light and Lighting” first saw the light of day! Although actively engaged in developing the use of prisms for scientific lighting, we took a great interest in the new publication, known then as “Illuminating Engineer.”

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small measure to show the public the value of artificial light applied scientifically for a particular purpose and to foster the upward trend in lighting generally.

The year 1931 was important in the history of floodlighting in this country for the eighth session of the CIE provided an incentive to light some notable buildings which hitherto had not been attempted. One outstanding example was the lighting of the clock tower of the Palace of Westminster. The highly successful result of this effort added to the ever-growing interest in floodlighting.

Lighting of gardens was another application of floodlighting which began in the early 1920s. Before that time "fairy" candle lights and "Chinese" lanterns were the fashion for garden parties, though some small outdoor lighting schemes had been carried out as early as 1909 using carbon filament lamps. The development of floodlighting equipment for buildings changed the situation completely, for with this equipment it became possible to produce wonderful night-time scenic effects in gardens, specially with the judicious use of colour. Some good results, incidentally, were obtained by using coal gas as the illuminant in specially designed floodlights. These were used for lighting the flower beds in St. James's Park in 1931 and again for the Jubilee in 1935, when a big increase in exterior lighting was evident. Gas was used successfully also for floodlighting important buildings throughout the country, including Worcester cathedral, Birmingham town hall and many others of equal note.

#### For National Celebrations

The year 1937 is noteworthy because it was the first year in which it became possible for effect lighting to be incorporated in the external decorations for a national celebration. For the coronation which took place that year much imagination and ingenuity was displayed in many of the decorative schemes for the event, thus providing evidence of close co-operation between designers and the lighting engineers.

Floodlighting then became commonplace till the beginning of the 1939-1945 war when it ceased completely until the victory celebrations in 1946. The river display on the Thames to celebrate this occasion was a good example of what can be done by improvisation. It will be remembered by all who saw this spectacular display how 24 invasion barges were lined up on either side of the river between Charing Cross and Vauxhall, each containing NFS emergency pumps. Jets of water from these pumps were lit by floodlights in various colour schemes. More remarkable still were the fire boats stationed in the centre of the river which spouted jets up to 200 ft. lit by 12-volt lamps in army headlights fed from the starter batteries. All this was accomplished within six weeks, using lighting and pumping equipment which had seen service in the Navy, Army, Air Force and NFS during the war.

The temporary fountains which were installed in St. James's Park for the same occasion had underwater floodlighting with changing colour and attracted many thousands of people, while the fountains in Trafalgar Square were also lit for the first time.

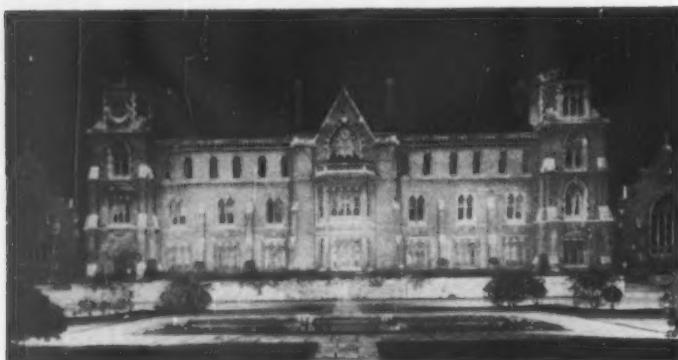
About this period discharge lamps were first used as light sources for floodlighting. Both sodium and mercury lamps have been used effectively, though latterly it has been demonstrated that hot-cathode fluorescent lamps are sometimes preferable. A mixture of tungsten lamps with either sodium or mercury lamps has also proved effective. By careful planning, this



#### 1924-1931

**Above,** flood-lighting of a replica of the Taj Mahal at the Wembley Exhibition, 1924. **Right,** Royal Bank of Scotland, Burlington Gardens, and (below) the Palace of Westminster, floodlit in connection with the CIE congress. (Compare this photograph with that on page 59.)



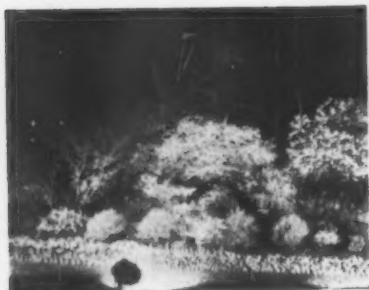


### GAS

Above, Tottenham and District Gas Co., Woodhall House, Tottenham. Right and below, four views of gas floodlighting in St. James's Park (1931 and 1935).

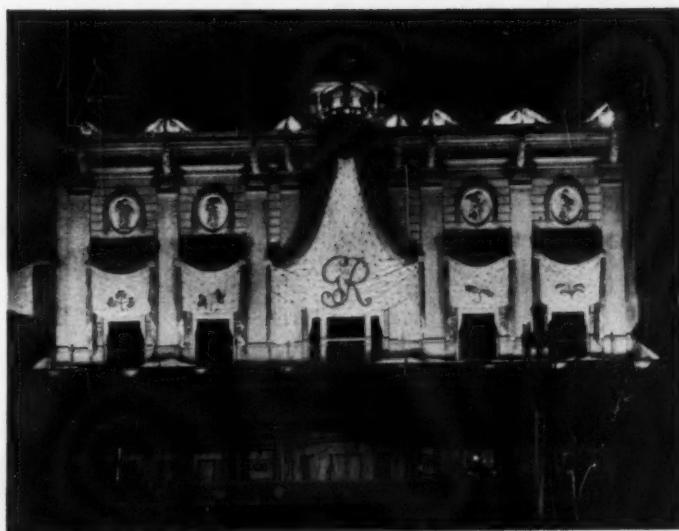
combination of light sources can be used to emphasise the shape of the building and to counteract the flat appearance a floodlit building sometimes has when viewed from a distance. Windsor Castle was treated in this way for the coronation in 1953, when, for example, the towers along the north front were lit by tungsten lamps while for the flank walls diluted sodium lighting was used. As a result the towers were brought forward and the flank walls receded, thereby producing a three-dimensional effect. At no time previously had the Castle looked so lovely at night, especially as the Round Tower was lit in such a way that its shape was revealed to perfection.

The lighting for the coronation in 1953 proved once again, this time on a greatly increased scale, the value of floodlighting for creating a festive



atmosphere for a national celebration. The decorative lighting was in various forms, from simple illuminated motifs to the spectacular display in the Mall, and was made all the more effective by a background of floodlighting which served to link the festive lighting with London. The aim was to produce an illuminated skyline, seen from Buckingham Palace, and the emphasis was, therefore, on the upper parts of the buildings within view.

Little need be said about the appearance of London at that time because it is still fresh in public memory, but the coronation illuminations illustrate an important aspect of floodlighting: that the upper portion of a building should be the target of the lighting, so as to add dignity and apparent height—in other words, to create a better perspective. Projectors are sometimes seen aimed at the base of a building, or floodlighting is taken too literally and a building is just "flooded with light" when, by a few trials, positions might have been found for the projectors that would have shown up the architectural detail. For example, a remarkable improvement was brought about in the appearance of Buckingham Palace when the original frontal lighting was replaced by long-range projector lighting from the sides.



### Functional Floodlighting

So far, mention has been made only of the decorative use of floodlighting, but during the last decade it has come into its own also in industry—in railway marshalling yards and docks, and on aerodromes and building sites. It is of interest to note that on some large building sites to-day it is customary to mount a battery of projectors at a high level so that they throw the light downwards. As a result, the night shift has similar conditions to the day shift, without the disability glare so common in the past. Then there is a more "popular" aspect of floodlighting—namely, in the service of sport. The lighting of tennis courts, both indoor and outdoor, was, perhaps, the first application of this type and much thought and skill went into the installations of the early 1920s. Later, floodlighting was used for a variety of games and, to-day, evening football matches are quite common. The problem of lighting such large areas for a fast game appears to have been successfully solved. Greyhound racing—now a national "sport"—depends for its very existence largely on efficient lighting, and we may yet live to see an evening Derby or test match. Such an event might serve as a counter-attraction to "Son et Lumière" spectacles. It should be noted, incidentally, that for the first British attempt at producing a Light and Sound spectacle fluorescent lamps on dimmers were used.

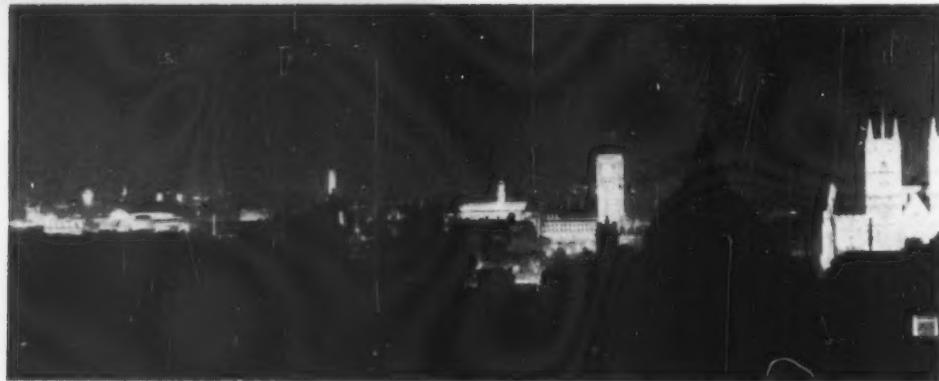
What of the future? It has taken many years to reach the present stage of development and to create public interest in floodlighting, but there is still scope for improvement, both in outdoor lighting equipment and in its application. Moreover, there is a need to make architects more conscious of the value of floodlighting and to persuade them to embody in their designs facilities for permanent installations. For large stores, with a canopy over the pavement, it is simple to provide these facilities and it may be possible to devise some method of housing a permanent installation for other types of building. Certainly we should try to avoid unsightly bracket floodlights which always look like an afterthought and often spoil the clean simple lines of modern buildings.

Consideration might be given also to the extended use of internally mirrored reflector lamps. They are very efficient and much easier to conceal



1937

Floodlighting for the Coronation of King George VI. Top, White's Club, St. James's St. Above, Palace of Westminster.



### 1953

Floodlighting for the Coronation of Queen Elizabeth II  
Top, Windsor Castle, lit by a combination of tungsten and diluted sodium-vapour sources.  
Right, from top to bottom : the skyline of London, seen from vicinity of the offices of Light and Lighting; Greenwich Palace; and the Horse Guards, Whitehall.

than large reflectors, as was proved by the coronation lighting, particularly that in the Mall where large reflectors were not allowed.

In conclusion, it should be said that, while floodlighting techniques have developed considerably since the early years of the century, one would hope that in the years to come greater attention will be paid to the aesthetic and artistic aspects of the subject. For example, it is difficult with modern buildings to avoid an appearance of flatness, although a careful mixing of light sources and the introduction of window lighting can help.

Each building has its own individual character and, if floodlighting is to flourish, this character must be taken into account when schemes are prepared. With the further development of bold and imaginative new techniques, it may even be conceivable that floodlighting will become the only source of illumination for our principal streets.

By L. G. Applebee, F.I.E.S.\*

## 10

# Entertainment and Sport

FIFTY years—how short a time it seems. To focus our minds on 1908 let us glance back at three outstanding events that occurred that year:—

The Olympic Games in London, with Dorando's dramatic "Collapse in the Marathon."

"Our Miss Gibbs" at the Gaiety Theatre.

The opening of Imre Kiralfy's White City Exhibition at Shepherd's Bush.

At the last, incidentally, one remembers the wonderful decorative lighting of the "Court of Honour"—so pleasing to the eye and, in this writer's opinion, as an example of outlining with incandescent lamps, more effective than the modern method of floodlighting.

What was the method of stage lighting used in the London theatres of 1908? The main distribution of light was from footlights and battens using electric lamps with carbon filaments. They were designated "16 or 32 candle power." Colour was obtained by "dipping" the lamp into what was described as clear lacquer or varnish, though the

Royal Opera House, Covent Garden, imported from Germany lamps the envelopes of which were made of coloured glass. These lamps remained in use until 1934, despite the introduction of the tantalum metal filament lamp (about 1911-12) and the gas-filled lamp after the 1914-18 war.

Directional lighting was by hand-feed arc spotlights, though in some theatres the "limelight" was still used. It was, in fact, still in use at the Theatre Royal, Drury Lane, as late as 1935. In 1914, at His Majesty's Theatre, Sir Herbert Tree used as many as 40 arc spotlights, each with its own operator, in his production of "Drake."

In several music halls and theatres in the suburbs and provinces, for the variety and pantomime productions of around 1911-12, the magnetic-fed carbon-arc lamp, of a type similar to those used for street lighting, was installed. Colour media that could be changed by wires or strings from the stage switchboard were provided. This was an innovation which started in Germany and was additional to the coloured lamps in the battens and footlights. The result was an indiscriminate flooding of light over every portion of the stage and scenery, with no thought of realism, it being the opinion of many theatre folk that it was desirable to flood as much light on to a scene as possible, even if it flickered continuously during the performance.

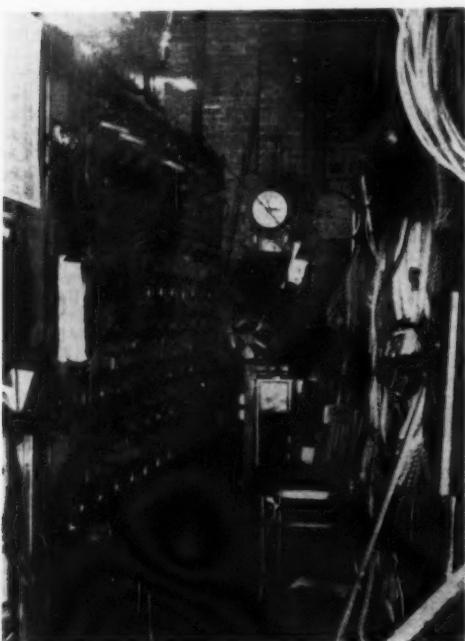
Control of the incandescent lighting was usually by open switchgear with liquid dimmers on most of the circuits. The latter remained the recognised method of varying the intensity until 1930, though there were one or two theatres in 1908, such as the Holborn Empire, the Palladium, the Gaiety and the Palace, Manchester, where wire-wound dimmers of German manufacture were used. Since 1932, many types of dimmer apparatus have been developed—e.g., resistances, transformers, electronic valves, and saturable reactors.

### The Projector-type Electric Lamp

Methods of stage lighting changed little until after the first world war, when two revolutionary developments took place. The first was the production of the projector-type electric lamp, which had made its appearance in America in 1914 and arrived in England in 1918. This lamp commenced immediately to take the place of the arc spotlight. It was a great advance: operators were dispensed with and, for the first time, it became possible to adjust the intensity of the light output by means of dimmers. Thus, the directional units could now be placed in positions which the operators had previously made impossible.

It is from this time that producers in Britain really commenced to use lighting as a medium of

\* Strand Electric and Engineering Co. Ltd.



1908

Stage switch-board and liquid dimmer regulator at the New Theatre, London. Installed in 1903; removed in 1950.



mood, form and realism in play productions. The spotlight makes it possible to light a small portion of the stage setting to a higher intensity than the rest of the scene and thus to concentrate the audience's attention on one particular area. It is with these units, too, that the producer gives an illusion of three dimensions to what is probably painted canvas. The first use of these units was in 1917 by Earnshaw in Chas. Frohman's production of "Peter Pan" at the Duke of York's Theatre, London, and by an American producer, Ben Rimo, in "The Willow Tree" at the Globe Theatre, London.

The creation of stage illusions by this method was aptly described by J. B. Fagan in the paper he read before the IES at the Royal Society of Arts in 1919, and further information on the subject was given by C. Harold Ridge in a paper to the Society in 1930.

#### Low-wattage Gas-filled Lamps

The second development was the appearance of low-wattage (60-, 100- and 150-watt) gas-filled lamps. Varnishing with colour was now impossible because of the high temperature of the lamp envelope, and other means of obtaining colours had to be devised. Thus, each lamp in the footlights and battens had to be housed in its own compartment, and colour was obtained by using the gelatine, which had hitherto been used only for the spotlights.

Up to 1919 much British apparatus had been developed by trial and error, but after this date lighting engineers began to design the units scientifically. They improved their efficiency and, what was more important, produced reflectors to project the light where it was wanted. A great incentive to the improvement of the efficiency of battens and footlights was provided by the introduction of a stage illusion by Adrian Samoiloff—an exile from Russia who produced at the London Hippodrome phenomena that, from the entertainment point of view, swept the town. They increased the box office takings by over £1,000 a week. Samoiloff's stunt enabled him to change George Robey, wearing a black tuxedo, into a Negro in green-and-orange-striped pyjamas. For his illusions he needed high intensities of light, and much thought was given to the design of reflectors. Various materials were tried, such as 'broken surface' mirror, stainless steel, etc., and these materials continued in use until 1947, when anodised aluminium was introduced.

The subsequent advance in spotlight design induced theatre producers to ask for such fixed units to be placed in the auditorium, directing their light beams toward the stage, and with the colour screens remotely controlled from the switchboard panel. The first use of this system was at the Theatre Royal, Drury Lane, for Noël Coward's "Cavalcade." Since then there has been a gradual increase in the number of spotlights placed in the auditorium, and to-day, at the Shakespeare Memorial Theatre, Stratford-on-Avon, and at the Old Vic there are more stage lighting units in the front of the house than on the stage itself.

With this progress came the need to design lanterns that not only gave increased light output,

#### 1944-1958

**Top:** remote-control panel as installed at Sadlers Wells Theatre, the Palace Theatre and the Piccadilly Theatre. **Left:** the stage of the Theatre Royal, Drury Lane, as lit for 'Oklahoma.'

but which were capable of efficiency at a long throw. Thus was introduced the "mirror spot." The efficiency of this device results from the use of an ellipsoidal reflector which gathers the light from the lamp filament and projects it on to a variable gate, before passing it through an optical system of lenses. One of the many advantages of the mirror spot is that a mechanism can be used to shape the resultant beam and mask off any of the light so that it does not spill on to areas not required to be lit.

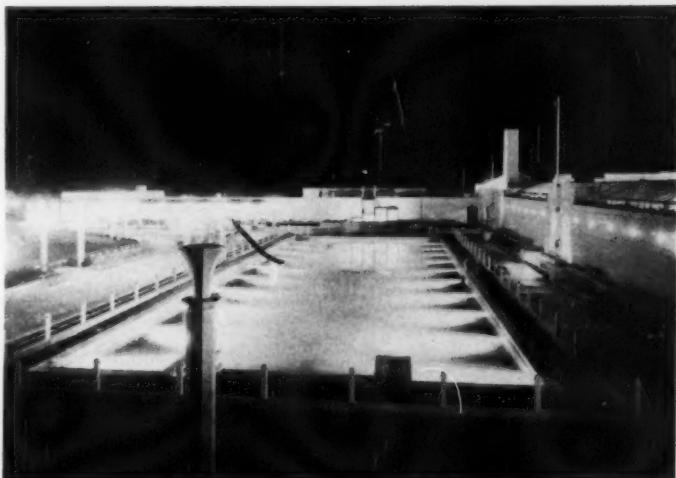
It was the mirror spotlight which eventually led lamp manufacturers to produce a type of projector lamp more suitable for theatre work. The lamp is designated the 'T' type and uses an A.1 filament in a B.1 round bulb envelope. It thus has many of the advantages of the B.1, but has the light output of the A.1. This lamp is also fitted with a pre-focus cap which ensures that it is always in the correct position in relation to the lens and the reflector.

An important item which was developed after the 1914-18 war was the 'cyclorama.' Germany started to make practical use of this form of stage illusion, though it was the idea of Gordon Craig, the son of the late Dame Ellen Terry, who advocated its use at the Moscow Arts Theatre in 1900. In effect it comprises a screen—sometimes portable and made of canvas, sometimes made of solid cement—on which coloured light is evenly projected to produce sky effects and to give the illusion that the audience is looking into infinite space. This effect is often enhanced by projecting either still or moving clouds on to the surface. In Germany seven hues were used, and the method was described in Lester Groom's lecture on "Problems of Stage Lighting" given before the IES in 1926. The cyclorama was used extensively by Basil Dean in many of his productions.

#### Methods of Colour Mixing

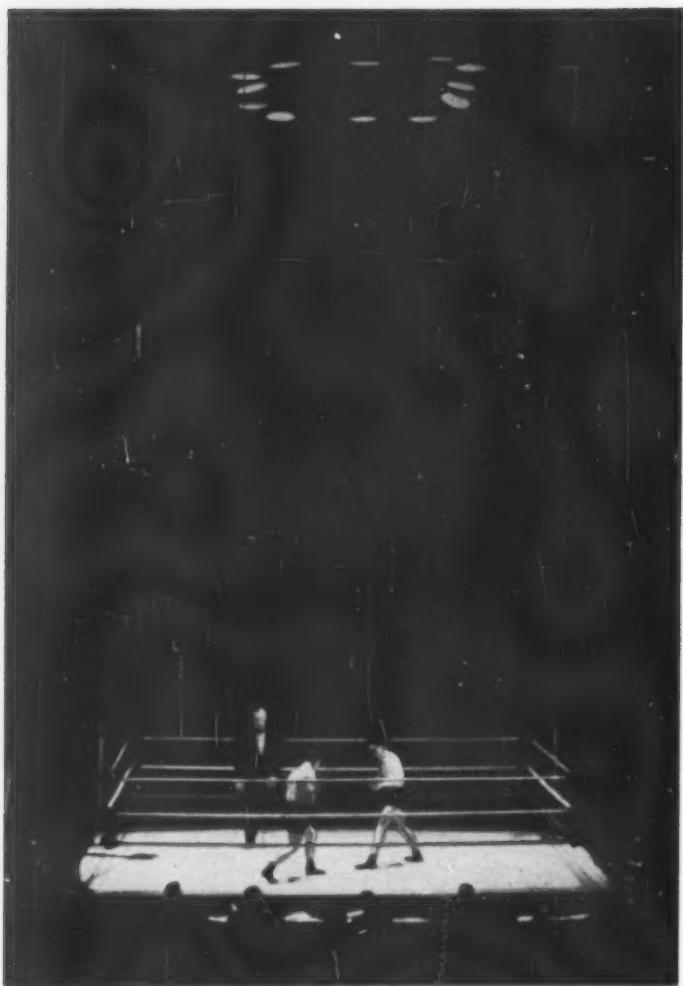
In 1926, or soon after, Harold Ridge began experimenting at the Festival Theatre, Cambridge, with the additive system of colour mixing, which had been advocated by Professor Young, of Emmanuel College, Cambridge, in 1805. Ridge was successful in producing various colours by varying the intensity of light behind each of three spectrally-pure coloured glasses, namely, red, blue and green. About this time Volk produced a large model stage, and on his cyclorama used theatre colour media (at that time gelatine). His attempts were exceedingly good and much finer than those that Ridge obtained. The colours he used were a deep blue in one unit, a greeny-blue in another, and red and amber in the third unit. The success of Volk soon spread, and thus the British method of lighting the cyclorama came into being, though theatres in the United Kingdom now use a deep orange in place of the mixture of amber and red for the top lighting, red alone being employed for the bottom or horizon lighting. Examples of this technique are to be found at the Royal Opera House, Covent Garden, and the Shakespeare Memorial Theatre, Stratford-on-Avon.

The successful mixing of colours was thought to be suitable for units other than those used on the cyclorama, and some manufacturers produced



#### 1909-1939

**Top,** swimming pool at new West Ham baths lit from above the laylights. **Centre,** open-air baths, Wembley, lit by floodlights on 20 ft. posts. **Bottom,** floodlit professional tennis at Olympia.



1938

The boxing ring. National Sporting Club, Earls Court.

apparatus that automatically mixed the colours to a predetermined hue. Their use in stage lighting in the United Kingdom was short lived, however, though they found popularity in ballrooms and dance halls.

It was during the 1939-45 war that further advance was made in the use of colour in stage lighting for large spectacles. The London Palladium revues devised by Robert Nesbitt demonstrated a new technique. The batten became secondary and, at last, the lantern known as an 'acting area' unit came into its own. This is a funnel-shaped device giving a concentrated light beam of 25 deg. Large groups of these lanterns were hung adjacent to the battens, giving a very strong down light on to the acting area. During the war, Robert Nesbitt's shows were a riot of coloured light, and the use of this technique has, since the war, spread to the big 'musicals,' the ballet, and the ice ballets staged at the Wembley, Earls Court and Harringay arenas. At the ice shows about 300 units are used to light the ice area and the sets, plus 14 100-amp high-intensity 'following' arc spotlights. These spectacles also make great use of 'black light,' and as many as 80 ultra-violet units are often used.

It is, however, in the control of stage lighting that most progress has occurred—spurred on

by the intricate requirements of the television studios. In the theatre to-day, the large number of dimmer-controlled circuits (there are 216 at Drury Lane and at the Coliseum) have made the manually-operated stage switch-board impossible—not only because of the large number of controls (as much as 15 ft. in length), but also because of the intricate cues that producers now require to be followed. Under these conditions, manually-operated controls would require three or four operators.

However complicated the cues, the various remote-control systems used to-day require only one operator. Thus, the remote control of stage lighting has come to pass and Fagan's prophecy in his paper of 1919, when he said: "The day is not far off when we shall see the electrician seated at his switchboard like a player at an organ," has truly been realised. Indeed, thanks to Frederick Bentham, the remote-control switchboard employs many of the techniques of the electric cinema organ. Great progress has been made in various types of control—for electronic, wire-wound, choke and transformer dimmers, and for magnetic amplifiers—and thus the stage keeps pace with the progress made in other fields of lighting.

## LIGHTING FOR SPORT

Let us turn now to lighting for sport. At an IES meeting in 1953, Mr. M. W. Pierce said that the first known example of lighting a football field was in 1888, by means of oil lamps, but there does not seem to have been any serious attempt until 1932, when the White City stadium was equipped with four towers, 120 ft. high, each with 40 narrow-beam flood-lanterns. The total load on all four columns was 160 kW. This installation is still in use, though some additional lanterns are now used for such events as the Royal Horse Show. As early as 1928, the Arsenal F.C. equipped its stadium with floodlighting, mainly for practice, but after the last war it was fully equipped for evening matches. More recently many football clubs, even some amateur clubs, have done the same.

One of the most successful examples is the Wembley stadium, where a double system has been installed—one for ball games and the other for tattoos, etc. Here, the total load is 340 kW. Incidentally, when the stadium was built in 1924, some American floods were used to distribute light in the area used for the big pageants and tattoos. The latest example is the Chelsea F.C. at Stamford Bridge, where the load is 480 kW, and there are six towers. At Manchester United, where the connected load is 324 kW., there are 224 1,500-watt units on towers 180 ft. high. The intensity on the pitch is 20 lm/ft<sup>2</sup>.

### As an Aid to Photography

Historically, the professional boxing ring is of interest, not only from the spectator's point of view, but also from the point of view of photographers. High-speed super-sensitive panchromatic motion picture films, which allow boxing and other sporting events to be photographed, were introduced by various manufacturers around 1931. Prior to this date it was necessary to use as many as 30 10-amp arc lamps of a type similar to old street-lighting units, together with the equipment necessary to give the correct arc voltage.

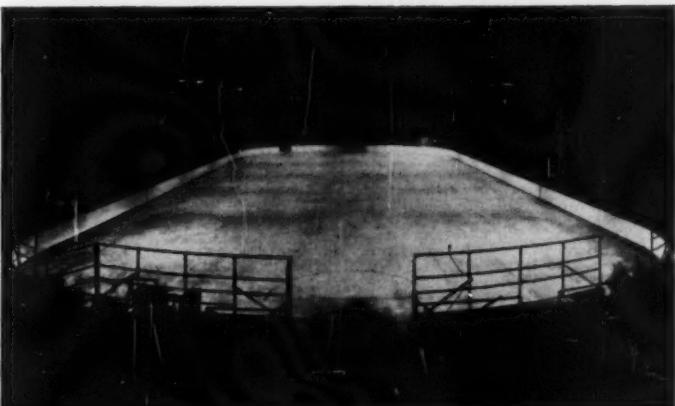
To-day, well-designed reflectors of a type similar to stage acting-area units and tungsten

lamps are used. At the Royal Albert Hall, 18 1,000-watt units of this type are installed.

Speedway and greyhound racing call for special directional fittings. These fittings are usually mounted 13 ft. above the track and at about 26-ft. centres. The result is what M. W. Pierce in his paper before the IES in 1953 described as illuminating the 'ribbon of the track.' 1,000- or 1,500-watt lamps are usually used.

Tennis brings to mind the very elaborate installations that were carried out when Sir Charles B. Cochran presented Mademoiselle Lenglen in professional tennis at the old Holland Park skating rink. Great care was taken to avoid glare in the players' eyes when they were serving and a frosted blue-tinted glass screen gave the light from the narrow-beam-angle 500-watt flood-lanterns a "daylight" appearance.

Ice hockey is an indoor sport that calls for a very high intensity of light and various types of scheme are in use in the arenas which cater for this entertainment. An interesting example is at the Wembley Pool, where mixed light is used—four tungsten fittings (1,000- or 1,500-watt) to one mercury-vapour unit.



#### 1944-1958

**Top,** the Derby swimming bath, Blackpool, equipped with stage-lighting apparatus for the annual summer 'aquashow.' **Right,** the ice rink, Earls Court, London. **Below,** floodlighting towers at Chelsea football ground.



## 11

# Lighting for Travel

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**F**IIFTY years ago artificial lighting was of little assistance to the traveller who journeyed after dark. The standard of illumination was low, and, apart from their inefficiency, some of the light sources then being used even contributed to the discomfort of passengers. Oil gas, which was used in most trains at the time, had the reputation of polluting the atmosphere by its characteristic smell. Horsedrawn buses were lighted by oil lamps which gave barely enough light for people to read the notices appearing therein—such as "Prepare to Meet Thy Doom," which, ironically enough, often appeared alongside the warning "Beware of Pickpockets"! Oil and acetylene lamps were commonplace in lighthouses and buoys.

Electric filament lamps were used in a few main-line trains, including Pullman coaches, electric trains and the underground trains, but many of these lamps were far from satisfactory and their output fluctuated wildly as the vehicle proceeded on its course. Even before 1908 an early edition of the *Orient Guide* drew special attention to the introduction of electric light aboard the Orient ships. An interesting extract states: "Here are no swinging, ill-smelling, blinding oil lamps, but the soft steady light of the electric lamps, which

seem to turn night into day on board and are motionless even in the roughest weather."

Before the 1914-18 war, however, good lighting was beginning to receive recognition. *The Times* reported on May 15, 1911, that "for some years the British Railways had realised the advantages of centralising their lighting matters under one department, presided over by a qualified Illuminating Engineer. This led to standardisation of lamps, burners, incandescent mantles and other fittings, and the department had gangs of maintenance men who carried out regular inspection of all equipment."

The North-Eastern Railway was the first to introduce this innovation, closely followed by the London, Brighton and South Coast Railway, and it is recorded that the railways were then spending £100,000 a year on lighting. A comment in *The Illuminating Engineer* during the same year pointed out the importance of the appearance and position of lighting fittings in railway coaches, and this observation was supported by the statement that "the public now not only expect to travel quickly and smoothly, but to be able to amuse themselves on a journey and read whilst doing so."

The new offices at Waterloo Station were, in 1911, lit throughout by tungsten filament lamps and an illumination level of  $2.5 \text{ lm}/\text{ft}^2$  was obtained on the desks.

Lighting in trains running between the Bank and Marble Arch was by tantalum lamps which provided an illumination level of  $1.0 \text{ lm}/\text{ft}^2$ . A higher level ( $1.6 \text{ lm}/\text{ft}^2$ ) was obtained from carbon lamps used to light a separate train which operated between Marble Arch and Shepherd's Bush.

## Electric Lighting for Cars

At the Motor Exhibition at Olympia (1911) electrical firms were offering electric lighting for cars as an alternative to acetylene as "small-voltage reliable filament lamps" were then available. This development made possible the lighting of the inside of the car, and a suggestion was put forward that movable headlights might be used for cornering, but no one at that time could possibly have guessed how many lamps would be used on a car 40 years later—headlights, side lights, rear lights, trafficator lights, brake lights, reversing lights, dashboard lights, spot lights, etc.

In 1908, lighthouses were equipped with oil lamps and, as these were low-brightness sources, very large and complicated optical systems were needed. Flashes were of long duration because

1908

Horse-drawn  
buses of 1908  
carried one or two  
meagre oil lamps.



it was not possible to obscure quickly the large optical system. Screens for occulting the beam were actuated by a weight which operated a clock-type mechanism.

Beacons and buoys of the era had automatic flashers and were lit by dissolved acetylene gas, stored in cylinders in the base. Replenishing took place annually when fresh cylinders were installed and the old ones taken ashore for recharging. Maintenance was difficult, as burners had to be cleaned and wicks trimmed and, when mantles were used, broken ones had to be replaced. Dusk and dawn switching was by an ingenious arrangement: a volatile liquid in a black container was vapourised by the heat absorbed during daylight and transferred to a transparent chamber where it condensed. The difference in weight between the two containers actuated a valve mechanism which turned the gas on and off.

In 1912, the illumination level on the platforms of main line railway termini was between 0.08 and 0.26 lm/ft<sup>2</sup>, suburban stations usually being at about 0.05 lm/ft<sup>2</sup>. The best lighting was provided on the underground platforms where illumination levels ranged between 0.18 to 0.38 lm/ft<sup>2</sup>, the lighting being helped by the good reflecting properties of the tiled walls. The light sources in common use were oil lamps, low- and high-pressure gas-mantles, flame arcs and tungsten filament lamps.

### Early Illumination Levels

Most railway coaches were lit by oil gas carried in cylinders under the coach, which were recharged *in situ* about once a fortnight from a gas plant at the sidings. As oil gas continued in use for cooking in dining-car kitchens until recently it is understandable that gas lighting was still to be found even after the second world war.

During the early part of the century escalator lighting was receiving attention and at Earls Court station ground-glass screens were fitted across the escalator shaft to protect descending passengers from glare. The Great Western Railway announced that it proposed to provide lighting to a level of 2 lm/ft<sup>2</sup> in its main-line third-class coaches and 2.5 lm/ft<sup>2</sup> in its first-class coaches.

In 1914 Liverpool station was re-lit with half-watt lamps, and about this time most of the railway companies re-arranged the fittings in their vestibule coaches to make the lighting more diffuse. The level of illumination remained at 2-3 lm/ft<sup>2</sup>, though it is interesting to recall that in the same year, J. S. Dow suggested that coach lighting should be improved to 7 lm/ft<sup>2</sup> from an indirect lighting system using the curved roof of the carriage as a reflector.

The first world war gave an impetus to air travel, and in 1919 an account of war-time methods of air-control lighting included a reference to coloured flares. It was suggested that, in future, group searchlights, coloured rockets and coloured illuminated ground screens might be used. This account was followed in 1922 by the first technical paper to the IES on aerodrome lighting. It was given by Lt.-Col. L. F. Blaity, D.S.O., R.E., who suggested a uniform system of aircraft identification lights, and red obstruction lights on high masts and buildings. A system of approach beacons was advocated and the illumination of the landing strip by flares or floodlights to provide 60,000-75,000 candles shining across the line of wind.

In the same year, 1,000-watt gas-filled lamps were used with dioptric lenses which concentrated the light on the landing area at Croydon airport.

The recommended level of illumination for railway station platforms remained at 0.25 lm/ft<sup>2</sup>



but station name boards were beginning to have individual lighting. The lighting at Waterloo station continued to improve under the guidance of Mr. A. Cunningham, who had introduced in 1917 sloping time-table boards lit from behind. The visibility of repeater signals was also improved—by the use of a white background lit by concealed gas sources.

The only change during the 1920s in the lighting of main-line railway coaches was the increasing use of bracket lighting over the seats, but the coaches of the underground railway were being equipped with 20 lamps per coach, and certain underground stations were equipped with roof searchlights to provide a beam of light which penetrated the dark sky so that the stations could

### 1908-1939

Above, early LMS first-class dining saloon built about 1904, lit by carbon filament lamps. Top, ship lighting between the wars—a typical example.

be more easily located from a distance. In 1928 the lighting load of underground rolling stock was consuming 6 million units of electricity a year.

When the Empire Exhibition was held in 1924-25, there was still a lot of gas lighting being used. At the Swindon works of the Great Western Railway and at Reading station a 50 per cent. increase in illumination had been achieved by changing from low-pressure to high-pressure gas. Victoria station was bathed in 125,000 candle power of lighting from 431 high-pressure gas mantles.

Motor cars were being equipped for the first time with internally-lit number plates, with glass covers that could easily be cleaned.

Meanwhile electricity was marching on. By 1928 Morden depot was lit by 500-watt floodlights. The fittings were at a height of only 30 ft. and each incorporated seven plano-convex mirrors and six lenses, but they gave 0.1 lm/ft<sup>2</sup> at a distance of 100 ft. and 0.04 at 160 ft. A coach station at Kennington was lit by tungsten lamps and, while the average illumination level was only 4.5 lm/ft<sup>2</sup>, at the actual loading points there were between 7 and 10 lm/ft<sup>2</sup>.

During the 1920s and 1930s much progress took place in the design and techniques of transport lighting but, because of adverse economic conditions, the benefits of this progress were not felt until after the second world war.

#### War-time Restrictions

As early as 1937, the Government appointed a committee to formulate regulations for restricted lighting on public vehicles and on railway stations, etc., which could be enforced in the event of the country being involved in hostilities. These regulations were introduced in 1939, and overnight all the improvements that had slowly been made since the early years of the century disappeared—to the disappointment of those who had worked so hard for better conditions. Instead of the IES recommendation of 0.25 lm/ft<sup>2</sup> for platform lighting made in 1912, the Government allowed only one per cent. of this (0.002 lm/ft<sup>2</sup>). The GWR, in common with every other public undertaking, had to abandon all ideas of providing a higher level of illumination for first-class than for third-class passengers. Both classes were reduced to the same figure—0.25 per cent. of the usual illumination

level at 0.006 lm/ft<sup>2</sup>. Blue or green colour-sprayed lamps, enclosed in a metal canister with a  $\frac{7}{8}$ -in. diameter hole, became the standard unit in all types of compartments.

For platforms, docks and marshalling yards, the fittings had to be of a cut-off type from which no light could be seen above 80 deg. from the downward vertical. These regulations proved very unpopular but, despite the public outcry, they continued in force until 1944 when air attacks on the United Kingdom became less frequent. They were then relaxed for railway coaches provided the windows were covered, though the improved lighting was completely extinguished during air raids.

Public movement in and out of stations and buildings was often effected through "light locks" which, besides allowing exit and entrance, ensured that no light was emitted from the building. These light locks gave a short period of adaptation and proved very helpful to the public during the years of "black-out."

#### Continued Use of Oil

To-day many stations are still lit with oil because they are too far from a suitable supply of gas or electricity. The railways regard oil as the most reliable source of light, and every train, including London's underground, still carries an oil rear lamp. Lanterns fitted with candles are also part of the railways' standard equipment, being available for emergencies when all else fails. Despite all the advances in light sources and techniques, about 20 per cent. of all railway lighting is still oil, there being about 30 per cent. gas and 50 per cent. electricity. There is still a surprising tendency to use bare lamps with specular backing reflectors rather than the more comfortable diffusing fittings.

Fifty-watt lamps in translucent shades are used by the London Transport Executive in its older underground stock, but 2-ft. 20-watt fluorescent lamps, operating on 850 cycles, have been fitted to coaches introduced since 1947. This high frequency, in addition to minimising the size of the auxiliary equipment, avoids interference with track signalling which uses superimposed pulses. New stock coming into service (1958) will use 5-ft. 50-watt lamps on 850 cycles, though as a long-term policy it may well be that coach

#### 1945-1958

**Left to right:**  
British Railways  
buffet car  
introduced in  
1957; modern  
platform lighting  
with fluorescent  
fittings, the name  
of the station being  
printed on the  
covers of the  
fittings; battery-  
operated buoy,  
with radar  
reflector.



builders will adjust the spacing of the ribs of the carriages so that 4-ft. lamps can be accommodated as an integral part of the interior.

Hot- and cold-cathode lighting is being introduced for stations, often with twin-lamp fittings which allow one lamp to be switched off to reduce the illumination level and the load during off-peak periods. (It is, incidentally, interesting to recall that Malden Manor station on the Southern Region was lit with cold-cathode tubing as far back as 1937.)

The improved lighting of stations has tended to reduce the visibility of signals, and these, in turn, have had to be improved. Fluorescent lighting is rapidly being introduced on the London underground railway, speeding up the movement of passengers and also reducing the risk of accidents, particularly on the escalators. Fluorescent lighting has also made easier the work of Customs officials at ports, airports and railway termini.

For many years the compartments of railway coaches on main lines have been fitted with special 20-watt and 30-watt lamps, fed from 24-volt axle-driven generators. In the dining cars 60-watt lamps are used. The system remains much the same today, though there are, perhaps, a few more lamps to a coach. Much interest is being shown in the use of fluorescent lamps for railway coaches—possibly having been stimulated by the fact that the Royal train shipped to South Africa in 1948 for the Royal Tour was equipped with fluorescent fittings.

### Changeover to Electricity

The main change that has taken place in lighthouses is the use of electric lamps instead of gas or oil. Type B.I. projector lamps are now used extensively and, because of the increased source brightness, optical systems are smaller, the buildings are smaller and the number of men required to maintain the equipment fewer. In modern equipment, two or more lamps are mounted on a rotating head or turret, which operates automatically if a lamp fails, bringing a replacement into use immediately. A lighthouse of 1908 gave an intensity of about 100,000 candelas, whereas a 1-kW B.I. projector lamp in the same optical system gives 1,350,000 candelas.

While many navigation buoys and beacons still work on the old gas-cylinder principle, there has been a growing tendency since the second world war to change over to lead-acid batteries designed to fit in the space formerly occupied by the gas cylinders. Batteries have the great advantage that they can be re-charged on the spot from charger on the maintenance vessel. It is of interest, incidentally, that the use of electrical equipment makes it easier to recruit maintenance staff.

Most navigation lights now incorporate photoelectric devices for dusk and dawn switching, and radar reflectors to increase their usefulness in fog.

Modern aerodrome lighting is vastly different from the hand-placed flares and cross floodlighting of earlier years. It must, of course, cater for aircraft which are larger, heavier and fly at greater speeds, and the volume of traffic at busy airports is so dense that the lighting has to assist in the rapid handling of the aircraft, with as many as 60 take-offs and landings an hour.

Wartime experience on Service stations laid the foundations for the modern system of visual landing aids, and it is no exaggeration to say that the British system has contributed most to the uniform arrangements now found at nearly all international airports. In brief, the system enables a pilot to make the correct approach for a successful landing by creating a pattern of light on the



**1945-1958**

Above, tourist-class lounge aboard the new Empress of Britain. Cold-cathode concealed lighting is supplemented by downlights. Left, terminal building, Renfrew Airport. Ceiling-mounted fittings house both tungsten and fluorescent lamps.



ground. Lights on the boundary of the landing strip indicate where he must touch down and, having landed safely, the pilot follows the taxi lights to the apron and so makes room for the next arriving aircraft.

There has been a complete break away from past practice in ship lighting. The restricted head room on modern ships has been responsible for an increasing use of cornice lighting, using hot- or cold-cathode fluorescent lamps, and shallow, ceiling-mounted canopies or decorative luminous features.

What progress may we expect during the next 50 years? Already the electric tram has disappeared from many large cities, and trolley buses may not be retained much longer. Perhaps new types of vehicles will be introduced, setting lighting engineers new problems. Oil and gas are being used less and less and electricity more and more; perhaps new types of light sources will become available. Perhaps the next review, covering the period 1958-2008, will deal with electro-luminescent panels in spaceships; who can say?

## POSTSCRIPT TO FIFTY YEARS

By 'Lumeritas'

THE Editor has packed the pages of this special issue with interesting articles covering progress in lighting during the past 50 years. The story told has not been dramatised, yet it records some revolutionary innovations. Of these, the modern discharge lamps and their extensive application to both indoor and outdoor lighting are clearly outstanding. What will the next half-century bring; lighting by electroluminescence, dynamic lighting and/or . . . ? The full significance of events is rarely appreciated at the time of their occurrence, and particularly is this true of events which are somewhat protracted in the happening—like the "industrial revolution of the nineteenth century" and the lighting revolution that can now be seen to have occurred in some fields during the first 50 years of *Light and Lighting*. So it is wise to indulge in retrospection from time to time, both to draw satisfaction from whatever good we see has been accomplished and to see what yet remains to be done.

Perhaps it is a little curious that most—if not all—of us indulge in no special celebration on attaining the age of 50, but tend rather to find this achievement accompanied by some regret—regret that we cannot reasonably count on going as long again and that so many years have gone of those we may expect to live. There may be unmitigated elation if and when we become centenarians, but of this I cannot yet write as from personal experience! Yet the completion of 50 years of married life is often the occasion for special rejoicing and we would probably be more than a little disappointed if having completed 50 years of public service, or of service to some other body, the occasion was not marked in some special and pleasurable manner. But a technical journal—though it may not, like Tennyson's brook, go on for ever—can celebrate its fiftieth birthday with unalloyed satisfaction. For, although it has reached maturity, providing it maintains its vigour and serves the needs of successive generations of readers, it has not a relatively short but an indefinitely long life still before it.

Three years ago this journal published a Directory of Manufacturers of Lighting Equipment containing the names of about 250 such manufacturers. But, looking down the list of advertisers in *Light and Lighting* in any one issue I find that only about 10 per cent. of the members of the lighting industry advertise their wares in the journal. Consequently, as one of the large number of lighting users who wants to know what equipment is available, I find myself—as others must be—in ignorance of many items from which I might choose what I need, or what I might recommend to other users. This is a pity, but it is no fault of the Editor and publishers. And, despite the assurance in last month's Notes and News, that it is not the policy of the journal to carry an overwhelming number of advertisements, it seems to me that substantially more manufacturers should, in their own interests, announce their products in the advertisement pages of the journal, instead of hiding their lights under bushels. Many of us are so pressed for time nowadays that we naturally tend to accept what is brought to our notice rather than search for something which might suit our purpose better if we could find it.



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